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RADIOLOGY AND RADIATION THERAPY
Textbook for the third year students of medical university

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The textbook gives modern data on bases of radiology and radiation therapy. Algorithms and diagnostic criteria of the basic diseases of bones and joints, respiratory, cardiovascular, digestive, urinary systems are presented. Main principles of radiation therapy are stated. The textbook contains information on radiation doses in radiology, possible harmful effects of radiation therapy and methods of irradiation restriction.

The manual is intended for the third year students of the faculty of foreign students.

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GLOSSARY

2DE	Two-dimensional echocardiography
A/kg	Amperes on kg
B-mode	Brightness mode
C/kg	Coulomb/kilogram
CA	Contrast agents
CAD	Coronary artery disease
CRE	Cumulative radiating effect
CT	Computed tomography
CTV	Clinical target volume
CdS	Crystals of cadmium sulphide
DSBs	Double strand breaks
EPC	Endoscope pancreatic cholangiography
FDG	Fluorodeoxyglucose
Gd-DTPA	Gadolinium- diethylenetriaminepentaacetic acid
GT	Gastrointestinal tract
GTV	Gross tumour volume
Gy	Gray
HBO	Hyperbaric oxygenation
HCT	Helical CT
HU	Hounsfield units
ICRP	International Commission on Radiological Protection
ICRU	International Comission Radiation Units and Measurement
IGRT	Image guided radiation therapy
IMRT	Intensity-modulated radiation therapy
IQ	Intelligence quotient
IU	Intravenous urography
IVC	Inferior vena cava
IVP	Intravenous pyelogram
J/kg	Joule on kg
LAO	Left anterior oblique
LET	Linear energy transfer
LVC	Left ventricular configuration
M-mode	Motion mode
MRA	Magnetic resonance angiography
MRI	Magnetic resonance imaging
MTS	Metastasises
MUGA	Multigated equilibrium studies
NSD	Nominal standard dose

OAR	The-organ-at-risk
OER	Oxygen enhancement ratio
PET	Positron-emission tomography
PTC	Percutaneous transhepatic cholangiography
PTV	Planning target volume
PVO	Pulmonary venous obstruction
QF	Quality factor
R	Roentgen
R/h	Roentgen/hour
R/m	Roentgen per minute
R/s	Roentgen per second
RAO	Right anterior oblique
RBE	Relative biological effectiveness
RCC	Renal cell carcinoma,
Rem	Radiation equivalent in man
RP	Radiopharmaceutical
SPECT	Single photon emission tomography
SSBs	Single strand breaks
SI	System international
TDF	Time a dose fractionation
TNM	T = tumor; N = nodes; M = metastases system
TTD	Tissue tolerance dose
T	Tesla

PREFACE

Radiology in clinical practice in many cases gives the information necessary for statement of the diagnosis which is inaccessible to other methods of clinical examination. Radiation therapy is widely applied in oncology; more than half of oncological patients receive beam treatment. In predegree training of doctors of any speciality it is necessary to provide studying of bases of radiology and radiation therapy to give knowledge and practical skills of modern methods of diagnostic visualisation and radiation therapy in clinical medicine. It is urgent for students of medical university. At the same time, in radiology and radiation therapy the greatest share of population anthropogenous irradiation is realised. Students should also be aware of medical irradiation restrictions.

The textbook includes basic theoretical sections of radiology and radiation therapy for students of medical university. Principles of beam research methods are given. Questions of modern beam diagnostics are considered in sections of diagnostic radiology of the bones and joints, respiratory, cardiovascular, digestive, urinary systems. Physical and biological principals and methods of radiation therapy are presented. For all kinds of radiology and radiation therapy harmful influences and measures on restriction of a medical irradiation are specified.

The textbook will give students the information on principles and possibilities of modern methods of diagnostic radiology and radiation therapy. It will help to use methods of radiology and radiation therapy, methods of reading basic beam symptoms and syndromes in diagnostic images, restrictions of medical irradiation in clinical practice.

The characteristic feature of this textbook is the detailed information on medical irradiation restrictions, complex study of radiodiagnostics, its modern methods and possibilities. The extensive illustrative material is presented.

The textbook is intended for the third year students of medical university.

CHAPTER 1. PHYSICAL AND BIOLOGICAL BASIS OF RADIATION ONCOLOGY

Radiotherapy is a medical speciality which teaches to use ionizing radiation as the medical factor. The radiotherapy is used in oncology. In the basis of ionizing radiation lies its biological effect.

Ionizing radiation is electromagnetic radiation (x-ray and gamma ray photons) or particulate radiation (alpha particles, beta particles, electrons, positrons, protons, neutrons, and heavy particles) capable of producing ions by direct or secondary processes.

Biological effect of ionizing radiation is defined by two factors:

1. Radiosensitivity of tissues and organs essential to the survival of an organism.
2. The absorbed dose of radiation and its distribution in space and time.

Today, as well as in the times when radiotherapy was discovered, its general problem consists in achievement of maximum selectivity of tumours destruction with the minimum consequences to normal tissues.

The basic features of biological effect of ionising radiation in comparison to other physical factors are:

1. Big discrepancy between insignificant amount of the absorbed energy of ionising radiation and the extreme degree of expressiveness of reactions of a biological object up to lethal effect (the basic radiobiological paradox).
2. Absence of specific receptors in a human body, perceiving ionising radiation.
3. The latent character of beam effects, especially of irradiation in small doses, presence of the latent period (in a wide range of doses).
4. Possibility of nonthreshold effect

1.1. Physical properties of various kinds of ionising radiation

X-rays are electromagnetic ionizing waves with length 10-0,001 nm (produced by roentgen machine or linear accelerator). Energy is 40 keV – 45 MeV.

Gamma-rays are electromagnetic ionising waves which are produced by decay (the process of disintegration of a radionuclide) or annihilation of electrons and positrons. Gamma rays are electromagnetic radiation similar to X-rays, light, and radio waves. In general, gamma rays, depending on their energy, can pass right through the human body, but can be stopped by thick walls of concrete or lead. Ionisation density of X-rays and gamma-rays in tissues is 1-2 pair of ions on μm . Energy is 1,25MeV.

Alpha radiation (α -particles) is a stream of particles with the weight equal to four, and double positive charge, i.e. a stream of nucleuses of helium atoms. The Alpha particle consists of two neutrons and two protons. Alpha radiation of natural

radioactive isotopes (energy to 9 MeV) possesses very small penetrating ability making in tissues of the man 50-70 μm . It is applied only in the form of the general or local radonic baths (^{222}Rn) in physiotherapeutic practice. Alpha particles with high energy (800 MeV), received on cyclic accelerators, possess high penetrating ability. Alpha radiation consists of heavy positively-charged particles emitted by atoms of elements such as uranium and radium. Alpha radiation can be stopped completely by a sheet of paper or by a thin surface layer of skin (epidermis). Ionisation density of alpha radiation in tissues is 3000-4000 pair of ions on μm . However, if alpha-emitting materials get into the body by breathing, eating, or drinking, they can expose internal tissues directly and may therefore, cause more biological damage. Alpha radiation of high energy are produced in cyclotrons for radiation therapy. Energy is 9 - 800 MeV. Symbol is α .

Beta radiation (β -particles) are the particles with negative or positive charge and weight, equal to 1/1840 weights of hydrogen atom. Beta radiation consists of electrons. They are more penetrating than alpha particles and can pass through 1-2 centimeters of water. Their energy varies in considerable limits: from minimum, practically zero, to maximum - in some millions elektron-volt. In general, a sheet of aluminum a few millimeters thick will stop beta radiation. Beta radiation of high energy are produced in linear accelerator for radiation therapy. Ionisation density of beta radiation in tissues is 50-70 pair of ions on μm . Beta radiation sources are natural and artificial radioactive substances (^{32}P , ^{90}Y , ^{131}I), and also linear and cyclic accelerators. Energy is 3 - 45 MeV. Symbol is β .

Neutron radiation is a stream of the neutrons representing elementary particles, without an electronic charge, with the weight equal to 1,00897 nuclear mass units. Neutrons are uncharged particles. Therefore, they do not produce ionization directly. But, their interactions with the atoms of matter can give rise to alpha, beta, gamma, or X-rays which then produce ionization. Neutrons are penetrating and can be stopped only by thick masses of concrete, water, or paraffin. In clinical practice fast neutrons with energy from 20 keV to 20 MeV are applied. The basic sources of neutrons used with medical purposes are accelerators and nuclear reactors (for a remote irradiation), and also radioactive californium (^{252}Cf) (for a contact irradiation). Energy is up to 20 MeV. Symbol is n .

Proton radiation is a stream of elementary particles with the weight equal to 1,00758 nuclear mass units, and a positive charge. Protons are nucleuses of hydrogen atoms, formed by ionisation of atoms of hydrogen. Accelerators are used as a source of protons for the medical purposes. Advantage of protons and alpha particles

received from accelerators in comparison with abovementioned kinds of radiation, is their ability to form a maximum ionisation in tissues in the end of the run that is called peak of Bragg. Thus the dose in peak surpasses that in surrounding tissues in 2,5-3,5 times. Energy is up to 200 MeV.

1.2. Clinical dosimetry

The outcome of beam influence is defined by radio sensitivity and the radiation dose in the irradiated volume and irradiation time.

A person doesn't have specific receptors perceiving ionising radiation. Though it should be measured and the results of its interaction with a substance should be registered.

The effect of interaction of ionising radiation with a substance can be observed in physical, chemical and biological environments that allows to distinguish physical, chemical and biological methods of clinical dosimetry. Each of these dosimetry methods includes the big number of ways of ionising radiation registration, not equivalent in accuracy of measurement.

Among physical methods the most widespread is registration of ionisation in gaseous and hard substances (the dosimeters equipped with ionization cameras, Gejgera-Mjullera counters, scintillating dosimeters and semi-conductor dosimeters) . Among chemical methods of dosimetry the photographic way is widely applied.

Biological methods of dosimetry have completely lost the value now and are not used in clinics anymore.

Ionisation cameras. At interaction of radiation with substance the energy of particles and photons is passed to atoms of this substance and causes their ionisation and excitation. Ionisation process arises in cameras with gas.

Under the influence of ionising radiation positive and negative ions appear in the gas filling the camera. Thanks to electric field the chaotic movement of ions becomes directed, when positive ions move to negatively charged electrode, and negative - to positively charged one.

In that case the electric current arising from ionisation is proportional to number of the ions formed in the chamber, and, hence, is proportional to intensity of ionising radiation.

Scintillation dosimeters. In penetration of radiation into a substance not only ionisation occurs, but also excitation of atoms and molecules. In some substances the share of primary radiation energy, converting in visible radiation, is great enough (about 20 % from energy of primary radiation). The substances possessing such ability are called scintillators. Some inorganic substances concern them, for example,

iodide sodium, iodide caesium, and also a certain organic substances (see chapter № 1).

Semi-conductor dosimeters. The method of semi-conductor dosimetry is based on ability of some substances to change resistance under the influence of ionising radiation. A number of the semiconductors possessing sufficient sensitivity can be used for clinical dosimetry. For example crystals of cadmium sulphide (CdS) which are the semiconductors. Semiconductors have conduction electrons, capable to move under the influence of a magnetic field, and electrons that does not suffice enough energy to become conduction electrons. This energy can be received by radiation ionising. In that case resistance of the semiconductor considerably decreases and arising electric current increases in proportion to intensity of radiation. Detectors made of cadmium sulphide have the small sizes (some cubic millimetres); a range of sensitivity varies from 1 to 120 roentgen/hour (R/h). These properties allow the usage of dosimeters with CdS for measurement of deep doses, especially at intracavity dosimetry.

Photographic method of dosimetry. Under the influence of an ionising radiation a latent image appears in emulsion. Chemism of the process consists in the fact that under the influence of radiation the bromic silver, being a basis of a photoplate sensitive layer, resolves and produces free atoms of silver. After that the irradiated sites become black. The degree of film blackening indicates the dose of radiation. This method is widely used in individual dosimetry.

Thermoluminescent method of dosimetry. Thermoluminescent method of dosimetry allows to measure the light energy precipitated when irradiated detectors are heated to certain temperature. Advantages of these detectors are following: they have small sizes, they are not connected to a measuring device, have a wide range of doses, with the help of these detectors the measurements can be carried out after irradiation. To produce these detectors compositions made of fluoric lithium and calcium compounds are used. This method is widely used in individual dosimetry.

1.3. Kinds of doses and unit of their measurement

The dose is amount of energy absorbed by a mass unit or volume of irradiated substance. There are some kinds of doses: a dose in the air, on a surface, in the centre of the irradiated object.

The dose attributed to a time unit is called capacity of a dose.

Capacity of a dose is the energy absorbed in a mass unit or volume of irradiated substance for a time unit.

Dose: a general term denoting the quantity of radiation or energy absorbed. Used for special purposes, dose should be qualified; if unqualified, it refers to the absorbed dose.

The exposition dose represents a dose in free air, in absence of disseminating bodies. It is defined by degree of air ionisation and characterises, mainly, a source of x-ray and β -radiations. If a distance from a source to irradiated object increases the exposition dose decreases in inverse proportion to a square of distance from a source to an irradiated surface. Coulomb/kilogram (C/kg) is the unit of an exposition dose of x-ray and γ -radiations. Coloumb/kg is an exposition dose of x-ray and γ -radiations in which the interfaced to it corpuscular emission bears a charge in 1C of electricity of each sign in air. Conventional unit of an exposition dose of x-ray and γ -radiations is the roentgen (R). The X-ray is a dose that in 1 sm³ of dry air contains ions bearing a charge in one electrostatic unit of an electricity of each sign. 1 C/kg = 3880 R.

Capacity of an exposition dose is an exposition dose calculated per time unit. In SI it is measured in amperes per kg (A/kg). Conventional power units of an exposition dose are: a roentgen per second (R/s), a roentgen per minute (R/m) and a roentgen per hour (R/hour). There are following ratios between them:

$$1 \text{ R/s} = 2,58 \times 10^{-4} \text{ A/kg}; 1 \text{ R/m} = 4,30 \times 10^{-6} \text{ A/kg}, 1 \text{ R/h} = 7,17 \times 10^{-8} \text{ A/kg}.$$

The dose in roentgens or its derivatives, measured on the surface of an irradiated object or a body is called a superficial skin dose. The skin dose in x-ray and gamma radiation exceeds a dose measured in free air at the same distance from a source of radiation as the skin dose consists of the absorbed energy of a primary stream of radiation and energy of the scattered radiation, which gets to a skin mainly from superficial tissues. With increase of irradiation field a skin dose grows, as the volume of tissues in which secondary radiation is formed increases. At the same time the skin dose decreases with increase of radiation energy, as scattered radiation is shifted deep in a beam.

Absorbed dose is quantity of energy imparted by ionizing radiation to unit mass of a matter such as tissue. The absorbed dose is the basic quantitative indicator of ionising radiation influence on irradiated tissues. The units of absorbed dose are rad (rad, conventional unit) and gray (Gy, SI unit). It is characterised by quantity of energy absorbed in a mass unit of an irradiated substance. In SI unit of the absorbed dose is joule per kg (J/kg). This magnitude received the name "Gray" (Gy). Gray is unit of the absorbed dose, in which energy of ionising radiation in 1 J is transferred to the 1 kg mass of the irradiated substance. 1 Gy = 100 rads. Rad is the conventional unit of an absorbed dose.

Linear energy transfer (LET) is the average energy lost by ionizing radiation per unit distance of its travel through a medium. High LET is generally associated with protons, alpha particles, and neutrons, while low LET is associated with x-rays, electrons, and gamma rays.

Quality factor (QF): different types of radiation produce the same types of effects. However, the magnitudes of the effects can be quite different even though the doses (Gy) are identical. The extent of the biological damage inflicted by a given type of radiation increases with the linear energy transfer (LET) of the radiation. Linear energy transfer, similar to stopping power, is a measure of the amount of energy transferred per unit distance travelled by charged particles or photons. The more energy per unit distance is lost, the higher is LET and the greater is density of ions and free radicals in the charged particle. The latter phenomenon is the most probable reason for the greater biological effects of high LET radiation.

In radiation biology these differences are indicated by the relative biological effectiveness (RBE), the ratio of the doses from two different types of radiation required to produce the same effect. Conventionally the dose required from 250 kV x-rays is used as the standard for comparison.

Although the RBE is a more precise estimate of a radiation's biological effect than the quality factor (QF), its use is restricted to radiation biology. The linear energy-transfer-dependent factor by which absorbed doses are multiplied to obtain (for radiation protection purposes) a quantity that expresses the effectiveness of the absorbed dose derived from various radiation sources on common scales. For low linear energy transfer radiations (x-rays, gamma and beta radiation) the QF is approximately 1; for high linear energy transfer radiations such as alpha a QF of 20 is recommended. The QF for neutrons varies with energy from 2 to 11. The QF for high energy proton or neutron of unknown energy is 10.

Equivalent dose is a dose absorbed in a body or tissues multiplied by corresponding weighing radiating coefficient (quality factor) for the given kind of radiation. The radiating coefficient is used for the record of efficiency of various kinds of radiations. Notion of an equivalent dose is used to estimate the biological effect irrespective of a radiation kind. Unit of an equivalent dose in SI is the sievert (Sv). Sievert is the equivalent dose of any radiation absorbed in 1 kg of a biological tissue, creating the same biological effect, as well as the absorbed dose in 1Gy photon radiation. Conventional unit of an equivalent dose is radiation equivalent in man (rem). $1 \text{ Sv} = 100 \text{ rem}$.

Effective Dose is a value of influence of the ionising radiation, used as a measure of occurrence risk of the remote consequences of human body irradiation taking into account its radiosensitivity. It represents the sum of products of an equivalent dose in bodies and tissues and corresponding weighing factors. Weighing factors for tissues and bodies in calculation of an effective dose are multipliers of an equivalent dose in bodies and the tissues, used in radiation protection for record of various sensitivity of different bodies and tissues in occurrence of stochastic effects of radiation. Unit of an effective dose is sievert (Sv). Conventional unit of an effective dose is radiation equivalent in man (rem). $1 \text{ Sv} = 100 \text{ rem}$.

The deep dose is the dose measured at certain depth from a surface of irradiated object. The relation of a dose in depth to a dose in the free air, expressed in percents, is called relative, or a percentage, deep dose. The relative deep dose increases with the increase in distance from a source, energy of radiation and an irradiation field.

Decay (radioactive) is the process of spontaneous disintegration (transformation) of a radionuclide. The activity of a radioactive substance is decreased.

The extent of a radio-activity of any quantity of radionuclide, being in the given power status at present is called activity. In other words, it is a measure of radioactive substance quantity, expressed by number of radioactive transformations per unit of time. In system of SI activity unit is a inverse second (s^{-1}), named becquerel (Bq) equals to one decay per second. Earlier used conventional unit of activity curie (Ci) equals to $3,7 \times 10^{10} \text{ Bq}$.

1.4. The basic stages of biological action of an ionising radiation

The first is purely physical stage of interaction proceeding for milliard shares of second. It consists in transfer of a part of photon (particle) energy to one of atom electrons with the subsequent ionisation and excitation of atoms (molecules).

The increased chemical reactivity is characteristic of ions and the excited atoms possessing extra energy, borrowed from a photon (particle).

The second is a physical and chemical stage of radiation interaction with substance. It occurs depending on structure of irradiated substance. Presence of water and oxygen plays the major role in the irradiated system. If water and oxygen are absent, the possibilities of chemical influence of the atoms activated by radiation are limited and localized. In presence of water under the influence of radiation there are positively charged ions of water H_2O^+ and dissolved electrons in water. Joining one of the neutral molecules, electrons form H_2O^- . Water ions, as well as its excited

molecules, are chemically active and are less stable, than non-excited molecules. In presence of the dissolved oxygen these active products of irradiation easily react with them, forming longer lived and chemically active forms, as free radicals: hydroxyl free radical OH^\bullet , superoxide free radical O_2^\bullet , hydroperoxid free radical HO_2^\bullet , and also peroxide of hydrogen H_2O_2 . Free radicals are neutral (uncharged) atoms or molecules with unpaired electrons. They are extremely reactive. Within a microsecond of their formation they may react with some molecule (the target) and damage it. Hydrogen peroxide has the potential to be highly damaging to cellular constituents. It is much longer lived than free radicals and can travel substantial distances in a cell, even across membranes, to attack its target.

The third is a chemical stage of beam influence. It lasts, as a rule, several seconds. At this stage there are biochemical damages of biologically important macromolecules (nucleinic acids, lipides, proteins, carbohydrates).

They distinguish direct action of radiation when there is a direct interaction of an ionising radiation to critical molecules, and indirect action through products radiolysis of water.

It is supposed, that indirect action prevails in low LET (brake, scale - beta radiations), and direct – in high LET (alpha rays and neutrons).

Direct effects. These are effects produced when the initial interaction of radiation (e.g. alpha particle, beta particle or electron) takes place with the target molecule.

Indirect effects. These are effects mediated by free radicals. The primary interaction of radiation takes place with water. It results in free radicals that damage the target molecule(s). Free radical hydroxyl (OH^\bullet) consists of various free radicals and is believed to mediate the most damage.

The basic arena of ionising radiation action on live systems is «atoms live» - cells and endocellular structures.

Chromosomes are critical endocellular structures in ionising radiation. They consist of nucleinic acids – keepers of the hereditary information and special proteins. As the majority of cells have only one or two copies of each molecule of DNA, a chromosome's defeat will be more significant, than in a case with a molecule with thousands of copies (for example, enzymes).

Under the influence of ionising radiation electron separates from a protein molecule, forming a defective area without an electron. It migrates along polypeptide chains. Here, in lateral chains of amino acids free radicals appear. Such events occur as a result of direct action of an ionising radiation.

Under indirect action free radicals are formed in a result of interaction of albuminous molecules with water radiolysis products. Free radicals formation causes changes in the structure of protein what leads to infringement of its functions (enzymes, hormonal, etc.).

Membranes under ionising radiation influence become critical endocellular structures as well; changes in proteins and lipides which participate in formation of biomembranes can increase their permeability for various molecules. In lysosomes it causes unregulated emission of its catabolic enzymes into the cell what could be disastrous. Damage of the nuclear membrane can affect cell division and thus their viability.

In waterproof lipides, mainly, in the presence of oxygen, ionisation and excitation also causes formation of free radicals and peroxides with chain reactions of oxidation of organic conjunctions.

There are three major types of damage to the DNA: base damage, single strand breaks and double strand breaks.

DNA base damage. The most common influence of radiation on DNA. It occurs primarily due to interactions of free radicals with the nitrogenous bases. The "classical" (rather slow) repair mechanism operates in the following way: first the damaged section is excised by an endonuclease. Next the excised segment is resynthesized by a polymerase using the undamaged strand as a template. Finally ligases attach the newly synthesized segment in place. If the damage remains unrepaired, the cell may survive and reproduce although its function may be impaired. Or, the effect on the cellular metabolism may be severe enough to lead to a cell death.

Single strand breaks (SSBs). Only one strand of the DNA breaks but not the other. It is required approximately 10-20 eV per break. Break of carbon bonds in sugar molecules develop under the influence of OH^\bullet radicals. These breaks are quickly repaired. SSBs are not considered to be as important as either of the other two types of damage (fig. 1.1).

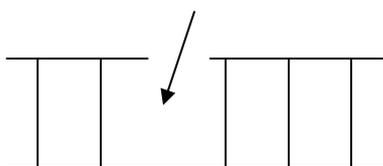


Fig. 1.1. Rupture of one DNA spiral

Double strand breaks (DSBs). Both strands of the DNA may be broken by a single event or by two separate events (fig. 1.2). The relationship between the dose and the number of double strand breaks appears to be linear-quadratic.

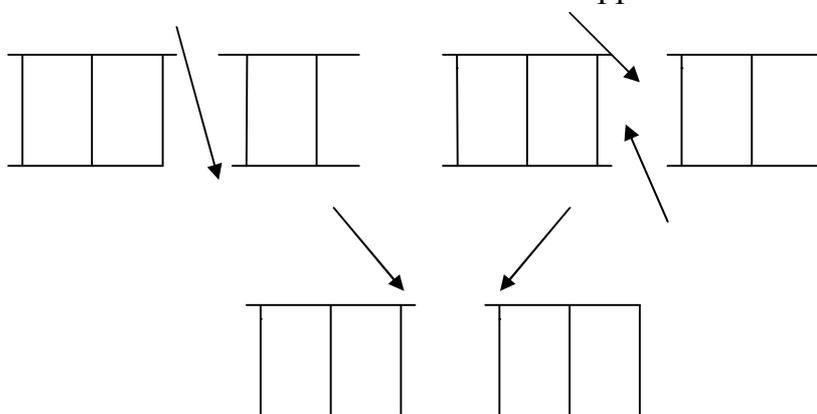


Fig. 1.2. Rupture of a double spiral of DNA.

Repair mechanisms for DSBs have not been identified. Double strand breaks, if unrepaired, result in broken chromosomes. The ends of the chromosomes at the place of the break are said to be "sticky" and tend to attach to other broken or unbroken chromosomes. The results depend on the stage of the cell cycle at which the exposure occurred, i.e., in G2 each chromosome consists of two DNA molecules (chromatids) whereas in G1 each chromosome consists of only one DNA molecule. The results of breaks in G1 are called chromosomal aberrations. The results of breaks in G2 are called chromatid aberrations.

Besides, under the influence of ionising radiation there are sutures between DNA threads, DNA-protein sutures, infringements of nitrogenous bases of DNA.

There are two types of DNA lesion consequences: the cell survives, but changes the functional status; the cell dies. Infringement of a functional status of cells can be expressed in delay or the change of cellular division leading to their uncontrollable growth (malignant tumors). It is well-known, that cells with the damaged mechanisms of DNA tend to turn to malignant cells and as well as malignant tumours contain the big quantity of chromosomal aberrations. Hereditary effects of an ionising radiation can be found throughout many generations.

Biological stage of a radiation injury. Among many examples of radiation influence on cell ability to live the most important property is to suppress the ability of its division. The destruction of cells can become apparent in a wide time range: from hours to years. According to the mechanism of cells radiation injuries it is necessary to distinguish two basic forms of destruction: interphase (not connected with a mitosis) and reproductive – destruction at the moment of division.

The nucleus plays a role of the keeper of the hereditary information of a cell, organism and even a biological kind, it passes this information from a cell to a cell, from an organism to an organism, providing successive communication of generations. This information is ciphered in chromosomes.

Chromosomal and chromatid aberrations are rings, fragments, dicentrics, etc.

Dicentric chromosomes, the chromosomal aberration most uniquely identified as being caused by radiation, can be quantitatively related to a radiation dose. In fact, a dose from an acute exposure can be estimated by counting the number of dicentrics produced and comparing this with the number known to be produced by the particular type of radiation involved.

Consequences of radiation damage to chromosomes:

1. Cell survives but with impaired metabolism.

The nature of the "malfunction" may be inconsequential or more severe. It may delay or alter cell differentiation and division, even resulting in cancer (needless to say, that dead cells don't become cancerous).

2. Cell dies.

High doses of radiation can result in the immediate death of a cell (interphase death) while lower doses may slow down a cell cycle.

A cell can divide and its death occurs after mitosis (reproductive death).

High doses of radiation can result in the immediate death of a cell (interphase death) while lower doses may slow down a cell cycle. The latter is due to a lengthening of G_2 brought about by some unknown mechanism. If the exposed cell passes through G_2 and attempts to divide, the survival of the daughter cells requires that each one receives a complete complement of chromosomes.

The above-mentioned chromosomal aberrations can prevent a proper distribution of chromosomes and result in the death of a cell during division (reproductive death). A chromosome should have a single centromere to divide properly; acentric fragments have none while fragments have two. The assumed involvement of double stranded breaks in the formation of chromosome aberrations and the absence of any known repair mechanisms for double stranded breaks leads to conclusion that they are most important contributor to cell death. However, other possibilities exist and considerable uncertainty still remains about the role of DSBs in cell death. Unrepaired single strand breaks or base damage can cause an incomplete duplication of the DNA in S. This in turn could lead to an unequal distribution of the DNA at mitosis and hence, cell death. Alternatively, radiation damage to the nuclear membrane is known to play a role in the behavior of chromosomes at mitosis.

For low LET radiation the most sensitive stages of the cell cycle, with respect to cell death, are mitosis and late G₁ (at the G₁-S border) although individual cell types show some variation in this regard. During mitosis the chromosomes are condensed and the repair mechanisms have poor access to the DNA molecule. During transcription of RNA the cell appears to be least sensitive to radiation damage because the uncoiled "open" nature of the DNA makes the repair mechanisms especially effective. All phases of the cell cycle appear equally sensitive to high LET radiation.

1.5. The major factors modifying radiosensitivity

Radiosensitivity is the ability of biological objects to react to action of ionising radiation by destruction processes and infringement of functions.

Bergonie and Tribondeau law can be used to interpret cells and tissues radiosensitivity, taking into account certain restrictions. The law was formulated in 1906 and it characterizes tissues which are most radiosensitive. According to the law, the most radiosensitive tissues possess cells which:

- a. are dividing at the time of exposure
- b. undergo numerous divisions in the normal course of their lifetime
- c. don't have a distinct differentiated type, i.e., unspecialized in structure and function.

Lymphocytes and oocytes which are highly radiosensitive being in interphase are exceptions.

Radiosensitivity of malignant tumor tissues doesn't have very big difference with normal tissues.

Oxygen tension. Cells containing normal levels of oxygen (40 mm Hg) tend to be 2-3 times more sensitive to low LET radiation than cells low in oxygen (hypoxic). For a given effect this difference is referred to as the oxygen enhancement ratio (OER). The relationship between oxygen and radiosensitivity is most evident below 20 mm Hg. Moreover, an increase in oxygen concentration does little to increase the radiosensitivity of a tissue. Poorly vascularized tissues, i.e., tumors, tend to be hypoxic; tissues well supplied with blood tend to have normal oxygen tensions. This effect of oxygen might be due to a resulting increase in the production of hydrogen peroxide. Another explanation involves the affinity of oxygen for electrons. Temperature as a modifying factor. In many experiments a dramatic increase in radioresistance has been produced by lowering of an animal's body temperature. The increase in radioresistance is apparently occurs due to a reduction in oxygen tension that accompanies a lower body temperature. If the effect is simply delayed it may be

due to a reduced mitotic rate; once the animal warms up and mitosis resumes, reproductive cell death can occur.

The success of radiotherapy depends on the greatest concentration dose of a radiation in a tumour and the directed change of a tumour radiosensitivity and normal tissues surrounding it by means of various methods.

Hence, the central problem of radiotherapy is artificial management of beam reactions of normal and tumoral cells for the purpose of the maximum damage of a tumour and preservation of normal tissues elements. The means enforcing beam reactions of healthy cells are called radio modifying agents.

1.6. Optimisation of radiotherapy of malignant tumours

There are three independent ways of optimisation of methods of beam therapy of malignant tumours on a radio biological basis:

1. Use of new technologies and new kinds of ionising radiation intended for peculiarities of their biological action and primary localisation of energy in the tumoral centre (in particular, it concerns the loaded nuclear particles).
2. Working out of irradiation modes considering distinctions of cytokinetic parametres of malignant and normal tissues, and distinctions in mechanisms of development of the direct and remote effects of an irradiation as well.
3. Development of artificial methods of healthy and tumoral tissues radiosensitivity management by means of various modifying agents of selective action.

Use of new kinds of radiations. So, along with traditionally used electromagnetic electronic and ionising radiation (X-ray and gamma radiation), the use of "new" kinds of ionising radiation for treatment of tumours is possible, namely heavy nuclear particles. Protons concern them, α -particles, negative π -mezons and neutrons. Except for the last, the listed heavy particles are charged and their application is calculated on increase of efficiency of radiotherapy at the expense of improvement of spatial distribution of radiation and its concentration in a tumour. The charged nuclear particles accelerated to great speeds in modern accelerators and after a certain (depending on their energy) run in tissues are slowed down and lose a maximum of the energy in the end of run, forming so-called peak of Bragg. If this peak occurs in a tumour zone, it is possible to lower radiation exposure to surrounding tissues along a beam and almost completely to exclude irradiation of the tissues which are behind the irradiated target.

Besides, deceleration of heavy charged particles causes:

1. Increase of their LET.

2. Additional increase of efficiency in a zone of Bragg peak occurs as a result of RBE increase.
3. The decrease of oxygen effect.
4. Difficultly repaired cell damages occur.
5. Levelling in radiosensitivity of a cellular cycle separate stages.

The set of these properties allows counting on additional increase of therapeutic efficiency of the heavy charged particles. Neutrons possess the same properties, however they have no Bragg peak, and their dose distribution is near to photon radiation what does not allow concentrating a dose in a tumour.

However taking into consideration all obvious advantages of using the bunches of heavy nuclear particles it is necessary to consider, that their application in wide medical practice is restrained by the big technical difficulties and demands considerable economic expenses. Besides, efficiency of their use is considerably complicated by difficulty of definition the exact borders of the tumoral centre because of tumour germination in surrounding tissues. It predetermines the necessity of irradiation volume increase.

Schedules of an irradiation and cytokinetic parametres. The first problem of radiotherapy consists in bringing of an optimal dose to a tumour. Optimum is a level at which the highest possible percent of treatment is reached at comprehensible percent of radiation damages of normal tissues.

In practice the optimum is a size of a total dose at which more than 90 % of patients with tumours of the given localisation both histologic structure and damages of normal tissues are cured, occur not more than in 5 % of patients. The importance of localization is highly important, as, for example, in treatment of central nervous system diseases even 5 % of brain necrosis is inadmissible.

The tumour 1 sm in diameter contains one billion cells (10^9). In that case theoretical calculations show the necessity of a unitary dose more than 30 Gy if cells are well oxygenated. For anoxic cells this dose should be increased more, than twice. Thus destruction of tumoral cells is inevitably accompanied by destruction of the healthy cells which are localized directly in a zone of irradiation.

For treatment of the primary tumour in case of its sizes increase a dose of ionising radiation should be increased as well. Thus the increase of tumour diameter per each more centimetre increases the additional irradiation dose in 3-5 Gy.

The data of theoretical calculations show, that a tumour with diameter more than 1 cm creates a difficult situation for radiotherapy.

Real calculation on radical treatment of patients without risk of reception of heavy beam damages can be only within cases of early clinical detection of a cancer.

Besides quantity of tumoral cells, other factors have also great value for the outcome of radiotherapy. These factors include radiosensitivity of cells, a saturation of cells oxygen, immune factors, etc. Thus, the tumour size is a determinative factor for the outcome of radiotherapy.

The biological effect is defined not only by quality of radiation, size of the single and total absorbed dose, but also by its distribution in time. At the beginning of the 20th century scientists have noticed that continuing irradiation of smaller doses gives more intensive biological effect, than a greater irradiation dose during the short period of time. Experimental and clinical data testify that the same total absorbed dose, but brought simultaneously or fractionally with certain intervals of time between irradiation fractions, gives various biological reaction.

On the final result of fractional irradiation influences:

1. Extent of the single absorbed doses.
2. Duration of breaks between irradiation sessions.
3. The general extent of irradiation course.
4. A total dose.

The influence of fractional irradiation on reaction degree can be judged by a following example. A unitary deadly dose of radiation for a dog is 6 Gy, and in 0,1 Gy daily irradiation dose the total deadly dose increases in 10 times.

Nowadays following methods are used in clinical practice:

1. One-stage irradiation.
2. A continuous irradiation (interstitial, intracavitary and applicational methods).
3. Fractional irradiation - one of the basic methods of an external remote irradiation. Following types are applied:
 4. Small fractionation 2 - 2,5 Gy (week 10-12 Gy),
 5. Average fractionation 3 - 4 Gy and
 6. Large fractionation 5 Gy and more - a single day dose.

In 1940th of the 20th century there was standard to have courses of tumours irradiation 5 times a week with 2 Gy per day. Such course consisting of 30 fractions by 2 Gy is widely used in modern radiotherapy and is designated as "conventional".

What processes occur in cells and tissues at fractional irradiation?

Most important of them are:

Restoration of cells from sublethal and potential lethal damages. This process begins during irradiation and, basically, comes to an end during the first 6 hours after irradiation.

The process second in duration is desynchronization of cellular population which in the result of irradiation becomes enriched in cells which were in radioresistant phases of a cycle during a session.

The third process - oxygenation - is specific only for tumours as they initially have a fraction of hypoxic cells. The death of part of the tumorous cells population especially oxygenated ones (and therefore more radiosensitive) reduces general consumption of oxygen by a tumour, what increases its diffusion in earlier hypoxic zones. Due to oxygenation under conditions of fractionation it is possible to deal with more radiosensitive population of tumorous cells, what is impossible in unitary influence. Oxygenation duration comprises 1-3 days.

The fourth process is repopulation of tumours and normal tissues. The greatest attention is paid to this process when modes of fractionation maximally increasing the therapeutic interval are developed.

Therapeutic interval is a difference between biological action of radiation on a tumour and on normal tissues.

Repopulation is usually defined as restoration of number of cells in the irradiated volume which has decreased as a result of beam influence. The term «accelerated repopulation» is used as well; it defines more rapid cells reproduction in comparison with reproduction before irradiation.

Reserve for accelerated proliferation is the reduction of cellular cycle duration, i.e. time of growth of a cell from one division to another, a smaller exit of cells from a cycle in a resting phase G_0 . After radiation influence the part of cells dies, and the remained cells have more oxygen, nutrients, outflow of exchange products is accelerated, pressure from the surrounded cells decreases. Earlier it was considered, that acceleration of a tissue weight increase is characteristic only for normal tissues. Now it is known, that accelerated repopulation occurs in tumours as well.

New modes of irradiation fractionation. Split-course is the course which differs from "conventional" one by presence of a 2-3 week interval in the middle of irradiation course. It has been offered to decrease the intensity of sharp beam reactions, which do not allow bringing a needed dose in treatment of tumours of some localisations (for example, in head and neck). Split-course saves the value in treatment of weak elderly patients or those tumour localisations (for example, in oral cavity) where sharp beam reactions block a continuous irradiation course.

Hypofractionation, i.e. use of a small amount of large fractions. A usual kind of hypofractionation is a large fractionation mode which includes some fractions in 5-6, or rarer 10 Gy. which are performed with an interval in 5-7 days to a total dose of 30-

45 Gy. Course of treatment lasts 3-9 weeks. The irradiation in this mode promotes a rapid stop of tumour growth, is well tolerated by patients and is very convenient for out-patient radiotherapy. In a hypofractionation mode the irradiation of metastasises in a bone is traditionally used. Use of 2-3 fractions in 6-8 Gy gives a fast anaesthetising effect.

If schemes of hypofractionation are mostly directed to creation of more convenient conditions for patients' irradiation, what gives the same result as a "conventional" mode, multifractionation modes are used to improve treatment effectiveness and decrease of beam complications.

Multifractionation is a mode of beam therapy with 2 or 3 sessions of irradiation per day. To determine various variants of multifractionation such terms, as hyperfractionation, accelerated fractionation are used.

Hyperfractionation is defined as the use of smaller doses per fraction, i.e. less than 1.8-2.0 Gy, in the same overall treatment time as used in conventional fractionation. In clinical practice hyperfractionation is usually applied as two daily fractions of 1.1-1.3 Gy. i.e. hyperfractionation often has a minor acceleration component (see below). The biological basis of hyperfractionation is to exploit the postulated different capacity of target cells in tumor tissue and late responding normal tissue to recover from sublethal radiation damage, taking into account that the time interval between the two fractions is sufficiently long. So, hyperfractionation might be useful to improve the therapeutic effect and to decrease chronic radiation damage. Thus, from a radiobiological perspective, hyperfractionation with increased total dose compared to conventional fractionation appears to be a promising option to improve local control and survival in some malignant tumors without increasing the risk of late normal tissue damage.

Accelerated hyperfractionated radiotherapy.

Accelerated fractionation is defined as the shortening of overall treatment time compared to conventional fractionation, or more precisely, as the application of an average dose per week of more than the 10 Gy used in conventional fractionation. In clinical practice accelerated fractionation is often combined with a decreased dose per fraction, i.e. a hyperfractionation component (accelerated hyperfractionation). Such hybrid schedules are best categorized according to their major difference compared to conventional fractionation. For example, if the overall treatment time of a radiation schedule is shortened from 6 to 2 weeks and the dose per fraction is reduced from 2 to 1.5 Gy, it is necessary to accelerate the treatment.

The biological basis of accelerated fractionation is to counteract the so-called time factor of fractionated radiotherapy, i.e. the loss of local tumor control with increasing overall treatment time. This time factor is generally explained by rapid repopulation of clonogenic tumor cells during treatment, which is supported by studies on tumor models under well defined experimental conditions. However, in clinical studies and in experiments, simulating the clinical situation, alternative mechanisms such as increasing hypoxia, increasing cellular radioresistance, or selection of highly malignant tumor cells might also contribute to the time factor. In contrast to tumors, overall treatment time has no or little impact on classical late radiation damage. Short overall treatment times increase acute normal tissue reactions.

Definition of tolerant doses at various modes of fractionation. The major condition of successful beam therapy is preservation of viability of normal tissues and the organs which are in a zone of influence of radiation. It concerns not only to anatomic structures surrounding a tumour, but also to the "target" which is exposed to the most intensive irradiation.

Besides tumour elements, it contains vessels and other connective tissue structures, regeneration ability of which influences the further course of disease. Even in annihilation of all tumour cells the disease outcome will be unfavourable if tolerance of normal tissues is exceeded. The resulting radiation injuries take a severe course as well as the basic disease. Tolerance is the maximum radiation dose not leading to irreversible changes of tissues. It depends not only on quantity of the absorbed dose, but also on its distribution in time. In conditions of fractionation irradiation the tolerance degree is expressed in the form of a nominal standard dose (NSD).

Concept of NSD is offered by F.Ellis (1969, 1971, 1973):

$$NSD = D / (N^{0,24} \times T^{0,11}), \text{ where}$$

D - the total absorbed dose (sGy); N - number of fractions of a dose; T - duration of treatment course, including first and last day.

Tolerant level of a connective tissue under concept NSD is equal to 1800 rad equivalent therapy (ret).

The amount of biological effect accumulates gradually with each subsequent fraction of a dose and consequently has received the name of "cumulative radiating effect" (CRE). It was offered by I. Kirk, Grey W., Etc. (1971).

It is expressed in the form of the formula:

$$CRE \propto V \times q \times d \times (T / N)^{-0,11} \times N^{0,65}, \text{ where}$$

\bar{d} is a single dose, sGy; \bar{V} is the deduction to the irradiated volume; \bar{q} is the factor of relative biological efficiency of radiation.

Unit CRE is “ure”. It is the unit of radiation effect. Tolerance of a connective tissue and a skin makes nearby 1800 ure, that corresponds to 60 Gy by the area of irradiation of 100 sm² and by a single dose in 2 Gy daily, 5 times a week. The given formulas are empirically proved in the numerous experimental and clinical researches which have received a general recognition. NSD and CRE can be applied in courses of therapy characterised by a regular rhythm of irradiation with number of fractions more 4, by a constant of a single dose and the general duration from 10 to 100 days in capacity of a dose not less than 20 sGy/minutes. Simple addition of CRE amount, for example, in splitted or recurring courses of radiotherapy, and also in change of irradiation rhythm is inadmissible.

To overcome these difficulties factor TDF - «time - a dose - fractionation» has been offered. Factor TDF was offered by C.Orton and F. Ellis (1973). It is based on the same preconditions and is expressed as:

$$TDF = N \times \bar{d}^{1,538} (T / N)^{-0,169} \times 10^{-3}, \text{ where}$$

\bar{d} a single dose, sGy, N - number of fractions of a dose, T - duration of course of treatment, including first and last day.

TDF corresponds to full tolerance of a connective tissue; it is accepted for 100, what corresponds to 1800 ure. Great advantage of TDF is possibility of simple addition of the values received at various treatment courses, differentiated in the rhythm. By mathematical transformations the possibility of TDF factor calculation for each separate fraction of a dose that allows to apply it at arrhythmic courses of radiotherapy with various single doses and intervals between separate sessions has been received. CRE and TDF are connected among themselves by a parity:

$$CRE = (TDF \times 10^3)^{0,65}$$

Doctors use in practical job corresponding schedules and tables for definition of tolerance and transition from one system to another, that is simple enough. Both systems CRE and TDF inseparably linked also have the advantages and lacks. In some cases it is possible to apply only factor TDF (for example, arrhythmic course of treatment), in others – only CRE (the refresher courses of treatment, the split course, the amendment on the irradiated volume). However transition from one system to another on final or the calculation intermediate stage is always possible. It is recommended to express an end result in «ure» since only such by it is possible to consider all important factors, including size of the irradiated volume.

Thus, the dose of radiation tolerable by an organ cannot be characterized as an absolute number. Rather, a dose of radiation to the entire substance of an organ may be associated with a certain probability of a radiation-induced complication. This concept is referred to as the minimal tissue tolerance dose (TTD). The TTD5/5 is usually used in clinical practice and is defined as that dose of radiation associated with a 5% rate of complications occurring within 5 years of treatment. The TTD5/5 is usually higher if less than 100% of an organ is irradiated. For example the TTD5/5 when the entire heart is irradiated is 45 Gy. When, however, only 20% of the heart is irradiated, the TTD5/5, is 60 Gy. As the dose/ fraction increases, the TTD5/5 decreases.

Radio sensitisation of tumours. Depending on sensitivity of tumours to radiation they are classified as radiosensitive which disappear completely after irradiation without necrosis of a surrounding connective tissue, and radioresistant which do not disappear in doses destroying a connective tissue.

Radiosensitivity of tumors:

- - high radiosensitivity: seminoma, lymphosarcoma, Ewings tumor, bazalioma of skin;
- - average radiosensitivity: squamous cell carcinoma;
- - low radiosensitivity: adenocarcinoma;
- - radioresistant tumors - fibrosarcoma, melanoma, chondrosarcoma, osteogenic sarcoma.

Radiomodification includes various ways of tumour radiosensitivity increase not only literally, but also by its relative increase by radioresistance reduction of healthy surrounding tissues.

Radio updating on the basis of oxygen effect:

Hyperbaric oxygenation (HBO) Radiobiological justification of HBO is very low (0-10 mm Hg) pressure of oxygen in tumour cells of. Oxygenation of these cells according to oxygen effect should lead to increase of their radio sensitivity. Thus normal tissues with oxygen pressure of 40 mm Hg and more possess the maximum radio sensitivity when breathing the air and do not increase in additional oxygenation. However carried out clinical tests have shown, that potential HBO possibilities are insignificant. Today a principal cause of it is considered to be an actual impossibility of delivery of enough oxygen in hypoxic zones, because great oxygen reactivity prevents from it. Besides, oxygen surplus leads to narrowing of blood vessels.

Radiomodification on a basis hyperthermia (thermoradiotherapy). High efficiency of hyperthermia as radio modifier is caused by several circumstances among which it is necessary to specify the following:

1. Hyperthermia possesses own damaging action at cellular level, and the effect depends on temperature and duration of heating.
2. Hyperthermia results in increasing radiosensitivity of cells because of temporary disorders in reparation processes.
3. Unlike ionising radiation hyperthermia decreasing concentration of oxygen in tissues does not lead to weakening of damaging and radiosensitivity effects. Thus, hyperthermia allows to overcome radioresistance hypoxic tumoral cells.
4. In hyperthermia another dependence of sensitivity on a stage of a cellular cycle, than that which is characteristic for ionising radiation is observed. So, the greatest radio resistance characterises the late S-period; when heating the period of synthesis of DNA is most sensitive. Last years it is believed, that damage of one of enzymes of DNA synthesis - DNA-polimerazy is key in a chain of all processes conducting both to thermal destruction, and to a thermal radio sensitisation.
5. Usually tumour cells possess the same thermosensitivity, as cells of surrounding normal tissues, but because of a number of features of a tumour: a low blood-groove, presence of sharply lowered values of pH in hypoxic zones, nutritious insufficiency, its cells are damaged more seriously than normal cells.

Chemical radioprotectors (cystamine, mexamine) haven't found wide application because of narrow spectrum of their therapeutic action: their application in nontoxic doses is ineffective.

CHAPTER 2. RADIOTHERAPY OF MALIGNANT TUMORS

Malignant tumors are capable of boundless growth and to extent by metastases. There are next special methods for treatment of cancer and other malignant tumors:

- surgery;
- radiation therapy;
- chemotherapy.

Today, more than 50% of patients with cancer will survive.

2.1. Establishing the diagnosis

Treatment of a malignancy can begin only after the tumor has been diagnosed. Recent radiologic techniques have dramatically improved the assessment for cancer, and we are now in the era of techniques such as computed tomography (CT), diagnostic ultrasound, and magnetic resonance imaging. Imaging procedures are invaluable in the staging of most solid tumors. Although the staging procedures used to depend on tumor type and location, the underlying principle is evaluation of the local and distant extent. Local extent is usually evaluated by the primary diagnostic modalities discussed above; this section will deal with the evaluation of common areas of metastatic disease. However, the only sure way to establish the diagnosis of cancer is by pathologic confirmation.

Guide to Therapy. Accurate assessment of tumor volume and local extent is particularly important when surgery or radiation therapy is used. Generally, the imaging studies recommended for primary tumors described above and in the specific chapters will give adequate information for a surgeon or radiation therapist. In most instances, CT scanning of solid tumors will give adequate information, although, as noted, there are occasions when MRI may be more useful. However, if ultrasound has been satisfactory in delineating the primary tumor, this method should be used for following response to therapy since it is cheaper. Metastatic lesions are also best monitored using the same modality which demonstrated them at the time of presentation.

Nuclear medicine studies can be an effective diagnostic tool. Bone scintigraphy is of less value than either CT or MRI in the evaluation of the extent of involvement by primary bone tumors but continues to be the most sensitive and easily performed modality for the early identification of skeletal metastases. Positive bone scans can result from abnormalities other than metastases, however, and any area that is positive on bone scan should be studied further by radiography. Positron-emission tomography (PET) utilizes positron-emitting isotopes and has significant potential for evaluation of physiological and metabolic activity rather than just anatomic structure. Labeling of antitumor agents may permit localization of neoplastic tissue. The necessity for a

nearby cyclotron to produce the positron-emitting isotopes limits the availability of the technique.

Arteriography is rarely indicated other than in primary liver tumors, although it should be considered when questions of blood supply or preoperative vascular embolization are raised.

Detection of Recurrences. Recurrent disease can be defined as reappearance of tumor in its original location or as metastases in distant sites. The primary site is usually best followed with the imaging modality used for the initial tumor. Adequate evaluation for metastatic disease requires knowledge of the natural history of the tumor; chest films, head and chest CT, bone scans, and abdominal ultrasound and CT are all reasonably used, depending on the organ of origin of the original tumor.

The vexing problem that has yet to be resolved is how often follow-up studies should be obtained.

Staging of solid tumors. The original concept of "stage" in solid tumors was a system designed to describe only the extent of disease at one point in the course, usually at diagnosis. A shorthand form was used, condensing the multiple types of possible extension of the disease into categories, exemplified by the TNM (T = tumor; N = nodes; M = metastases) system. They indicated which patients went to surgery or received irradiation and what type or dose. Surgeons, radiotherapists, and pathologists frequently modified (for different tumor types) the TNM staging system, and these modifications received the endorsement of national and international (UICC) organizations. In some tumor systems, the TNM classification was divided into a clinical stage (before surgery) and pathologic stage (after surgery and histologic examination).

In the era of effective surgery, radiotherapy and chemotherapy, the staging of solid tumors is an absolute necessity for comparing multi-institutional therapy trials.

Radiation therapy plays a major role in the management of most cancers. Because of the potential for acute and chronic side-effects, radiation must be used cautiously in patients. The severity of the side-effects is directly related to dose. Acute morbidity, such as gastrointestinal dysfunction, bone marrow suppression, and skin reactions, is seldom a limiting factor when radiation therapy is used alone, and the changes produced are generally reversible.

By ionizing radiation in malignant tumor next changes take place:

- reduction of tumour size
- development of granulation tissue;
- reduction of tumour vessels;

– destruction of all malignant cells and their substitution by connective tissue.

2.2. Principles of radiotherapy:

1. To achieve a favorable therapeutic ratio without producing unacceptable damage to adjacent normal tissues.

2. The radiotherapy has to be started in time. So much the better in I or II stages, when tumor is small.

3. For a favorable therapeutic ratio we must irradiate all tumor cells in necessary dose and in optimal time. The first course of radiotherapy is very important.

4. The dose is necessary if it is enough to plan effect. For radical treatment total doses of 60-70 Gy conventional fractionation are used. Primary tumor must receive this dose must. The regional lymphnodes must receive 50 Gy (in absence of metastases).

5. The favorable therapeutic ratio increases by using the factors which can increase radiosensitivity of tumour cells or radioprotect organs at risk.

7. Adequate diet, vitamins, giving up smoking and alcohol.

For favorable radiotherapy of cancer the tumor must be no more than 1 cm. Because for treatment of this tumor 60 Gy γ -ray conventional fractionation will be used.

The practical experience shows that result of radiotherapy depends more from radiosensitivity, oxygen enhancement ratio, immunity and some other factors. But the size of tumor is the principal reason for favorable radiotherapy. The limit of tumor size is 6,0 cm for successful radiotherapy.

Contra-indications for radiotherapy:

- Disintegration of tumor with abscess or bleeding, sprouting into hollow organs.
- Presence of many distant metastases.
- Bad condition of a patient.
- Exhaustion.
- Anaemia, low level of leucocytes ($< 3 \times 10^9$ /litre).
- Sepsis diseases, active tuberculoses of lung.
- Heart infarction (< 1 year ago).
- Heart, liver, kidneys insufficiency.

2.3. Variants of radiotherapy

Radiotherapy as an independent method of treatment can be performed according to a radical program. It can be used as palliative and symptomatic means of help to a patient.

Radical beam therapy is directed to complete treatment of a patient from a tumour and regional lymphnodes metastases by radiation doses killing cancer. Levels of cancer killing doses for various tumours are different and depend on their histologic structure, mytosis activity and degree of a differentiation of cellular

elements. Tumours which can be treated radically are skin, lip, nasopharynx, throat, breast, cervix uteri and endometrium, prostate cancer as well as seminoms, localized lymphomas, Hodgkin's disease, hypophysis adenomas. Clearly, the success can be reached at relatively early stages.

Palliative beam therapy is used for reduction of a tumour sizes and its metastases, stabilisation of tumoral growth; it is used when radiotherapy according to a radical program is impossible; and a total dose at palliative radiotherapy comprises, as a rule, 2/3 of a cancer killing dose.

Symptomatic radiotherapy is used for removal or reduction of clinical symptoms of malignant lesions, resulting in the fast death of a patient or essentially worsening of his life quality. Irradiation with symptomatic purpose is performed by vital indications in tumours of such localisations, when radiotherapy is the only method of treatment (superior vena cava compression syndrome, compression syndrome caused by a fast-growing brain tumour, sharp asphyxia by a fast-growing trachea tumour, spinal cord compression by primary and metastatic tumours). The total absorbed dose of radiation is determined individually, depending on the reached effect.

The combined treatment. This term is used, when operative treatment and radiotherapy is used in this or that sequence for special treatment of malignant tumours. Radiotherapy combined with surgical intervention can be used in the preoperative period, intra-operatively and postoperatively.

Preoperative irradiation is performed for improvement of conditions for radical operation and decrease in frequency of development of local relapses and the remote metastases.

Goals of preoperative beam therapy are:

1. Destruction of the most radio sensitive cells and decrease of viability of the remained tumoral elements.
2. Elimination of inflammation phenomena in a tumour and around it.
3. Stimulation and development of a connecting tissue and encapsulation of separate complexes of cancer cells.
4. Obliteration of minute vessels causing the decrease of tumour stoma vascularization and therefore the reduction of metastasis formation.
5. Conversion of tumours in an operable status.

The basic dose not exceeding 40 Gy, with 2 Gy daily within 4 weeks shows long-term experience in carrying out of the combined treatment; it does not cause difficulties in performance of the subsequent operation and does not influence the healing of a postoperative wound. The same can be told about other modes of

fractionation according to biological effect equivalent to 40 Gy by conventional fractionation (25 Gy for 5 fractions). The dose in 40-45 Gy leads to death of 90-95 % of subclinical centres of tumoral growth. Excess of a dose in 40-45 Gy can increase frequency of postoperative complications, though it is desirable for enhancement of a damaging effect on tumoral cells.

Nowadays two techniques of a preoperative remote irradiation are often used:

1. A daily irradiation of a primary tumour and regional zones in a dose of 2 Gy to a total dose in 40-45 Gy for 4-4,5 weeks of treatment.
2. Irradiation of similar volumes in a dose of 5 Gy within 5 days to a total 25 Gy.

In the first variant an operation is carried out in 2-3 weeks, and in the second – not later than 1-3 days; it is recommended only for treatment of patients with operable malignant tumours.

Postoperative radiotherapy increases the efficiency of operation by means of beam influence on implanted tumoral elements during surgical treatment (intervention). Postoperative irradiation, as well as preoperative is directed to prevention of relapses and metastases of a malignant tumour. Its goals are:

1. "Sterilisation" of an operational field from disseminated malignant cells and their complexes during an operative intervention;
2. Destruction of the remained malignant tissues after incomplete removal of a tumour and metastases.

Indications for carrying out of a postoperative irradiation are: in cases when radical operative intervention is impossible (brain tumours, tumors of pharinx, retroperitoneale space), a tumour exits the limits of that layer in which it was formed, its spread throughout the lymphatic system, organ-preserving operative treatment.

It is necessary to notice, that the postoperative irradiation is performed in conditions promoting increase of tumour cells radio resistancy (due to disorders in blood and lymph circulation). Simultaneously radio-sensitivity of normal tissues in a regeneration status increases. All this leads to reduction of a radiotherapeutic interval. However it is possible to note certain advantages of postoperative radiotherapy:

1. Volume and an irradiation technique are determined on the basis of the data received during an operation and after careful morphological studying of remote tissues.
2. Operative treatment is performed as fast as possible, after specifying the diagnostics.

Postoperative irradiation is performed if a postoperative wound is totally healed, 2-3 weeks after an operation. If malignant cells are absent in operational incisions conventional fractions in total dose of 50 Gy are used, if malignant cells are presented the irradiation dose equals to 60 Gy.

Intraoperative radiotherapy provides a unitary irradiation of an operational field or inoperable tumours during laparotomy with an electronic bunch with energy 10-15 MeV in a dose of 14-20 Gy.

Complex radiotherapy provides combination of beam and chemotherapy and pursues the double aim: mutual enhancement of ionising radiation and chemotherapy influence on a primary tumour (additive, potentiating and synchronising effects), and creation of conditions for preventive maintenance of metastases and treatment of subclinical or revealed metastases.

Two basic variants of complex treatment are distinguished:

1. Radiotherapy is the basic method, and chemo-hormonal therapy is an additional one. This method is directed to treatment of the remote metastases with total dose not lower than 60 Gy. So, in complex treatment of a non small lung cancer irradiation doses not less than 60 Gy are used for primary tumor, and 55-60 Gy for regional lymphnodes zones.

2. Ionizing radiation is used as a prophylactic means of radiotherapy in complex treatment. In these cases a dose of an irradiation can be 30-36 Gy. It is used in treatment of Hodkins disease and malignant lymphomas.

The variant of conventional fractionation dose is used, as a rule.

Multimodal therapy of oncological patients provides optimal use of modern methods of surgical, beam and medicinal treatment, and also their combination to radio modifying influences.

Nowadays a beam therapy of oncological patients is carried out by use of three basic ways of ionising radiation:

- 1) the external patients applied at 95-98 % which are subject to beam therapy;
- 2) brachytherapy (intra-cavity radiation, interstitial therapy);
- 3) systemic (intravascular, intrapleural), used no more than in 0,5 % of cases.

2.4. Treatment Planning

The main principle of radiotherapy is tumour treatment with the maximum protection of normal organs and tissues.

For its implementation in a clinic great attention is given to working out of ways to increase the efficiency of beam influence on the basis of spatial and time distribution of ionising radiation dose and application of the means changing (modifying) tumour and organism beam reactions.

The treatment planning of radiotherapy must begin with establishing the diagnosis of malignant tumor by clinical, radiology and oblige histologic examination. After that the consultation with a radiation oncologist, a surgeon and a

chemotherapist should be taken. Those actions are necessary because the treatment of malignant tumors is difficult and compound; complications are very hard.

The initial process in planning radiation therapy is to identify the target volume. For curative irradiation, the target volume usually includes the primary tumor site and immediately adjacent area of potential microscopic extension. Inclusion of adjacent or regional lymph nodes is dependent on tumor type and extent. Data from clinical examination, radiological studies, and operative assessment may be used to define the target volume. Knowledge of the natural history of specific tumor presentations is critical in determining the appropriate irradiation volume.

Once the target volume has been determined, an interactive process of patient simulation and dosimetry defines the treatment plan. Simulation permits accurate localization of the target volume from one or several directions; the simulator is a diagnostic-quality x-ray unit structured to mimic the treatment machine geometrically. The position and divergence of the photon beam are identical to those of the linear accelerator, allowing the radiation oncologist to plan accurately treatment strategies that have been identified by and may be later confirmed by computerized dosimetry. Planning seeks to maximize dose homogeneity within the target volume and permit appropriate dose limitation for critical normal structures.

Dosimetry provides a detailed analysis of the dose distribution within a given plane. CT-based treatment planning accurately displays the dose relation based on the planned field configuration (fig.2.1).

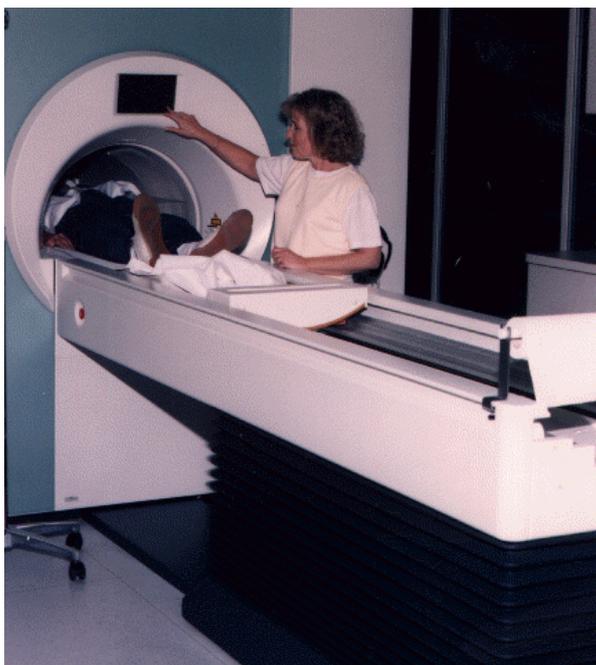


Fig.2.1. Computer tomography the basic radiological method for clinical definition of target volume at radiotherapy.

Simulator is ancillary radiation equipment. At the same time, for the account of physiological movements (basically, at breath) and the displacement of the irradiated volume connected with them, the method of visualisation working in real time is necessary: fluoroscopy. This research is carried out on the special diagnostic x-ray device – x-ray simulator (fig. 2.2).

There must be a mechanism of converting the concept of irradiating a certain amount of tissue into a practical plan. The specific number of radiation beams (also called radiation ports), their size, and their angles of entry into the body must be determined. The simulator is a machine that assists in the development of an actual treatment approach.

The simulator reproduces, or "simulates," the radiotherapy treatment machine (i.e., ^{60}Co or linear accelerator). The simulator contains, however, a diagnostic x-ray tube instead of a high-energy radiation source. The physician may plot the angles of the radiation beams and determine the beam size required and document each proposed "port" with a diagnostic x-ray.

This diagnostic film is used to show the tumor volume and the location of any appropriate lead blocks. In this way a high energy treatment plan can be developed without exposing the patient unnecessarily to radiation from cobalt or the linear accelerator.

Then the schemes of body section at "target" level are developed. Modern systems of dosimetric planning (computer systems for planning radiation therapy) perceive the information directly from magnetic carrier CT and print a map with the chosen distribution of isodoses put to it (fig. 2.3). Isodose lines connect points to identical value of the absorbed dose. Mark relative values - in percentage of the maximum absorbed dose accepted for 100 %.

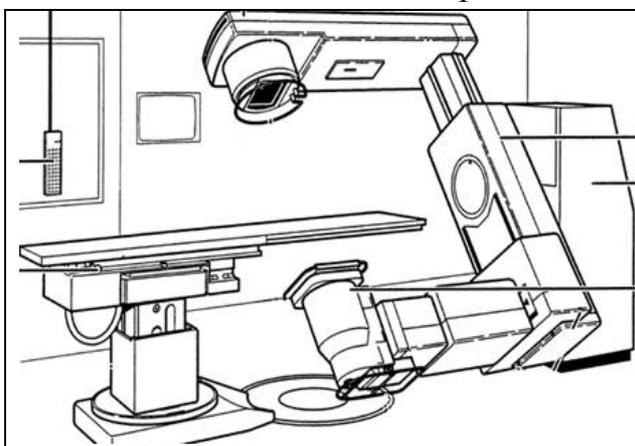


Fig. 2.2. X-ray simulator of an irradiation

To estimate isodose curves special computer programs which consider spatial parameters of irradiated object and the dosimetric characteristic of radiation are used. To make representation about distribution of the absorbed doses in the irradiated volume, isodose curves are plotted on schemes, thus, a map of isodoses appears. In radiotherapy a dose distribution is considered acceptable if the whole tumour consists in a dose of 100-90 %, the zone of subclinical distribution of a tumour and regional lymph nodes is in limits of 80 % of an isodose, and healthy tissue - not more than 50-30 % of an isodose.

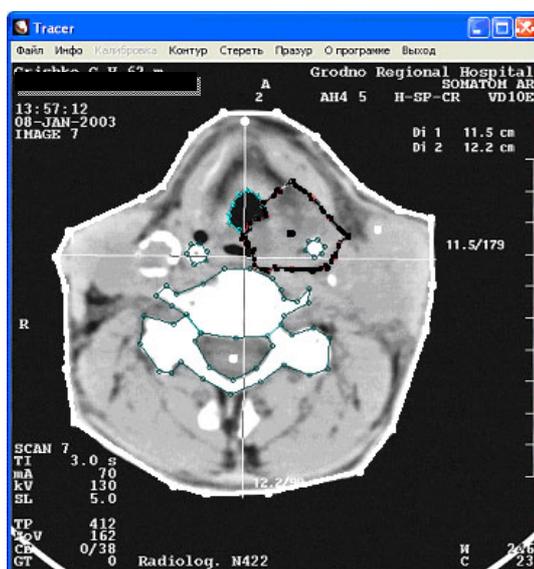


Fig. 2.3. Creation of contours on the computer tomogram for dose calculation in computer system of planning of an irradiation.

More complex field arrangements are often desirable, concentrating the high-dose volume or limiting doses to specific structures. In addition, blocks are customarily used to define the treatment volume. Customized blocks are fabricated from a lead alloy that provides precise beam definition to limit the irradiation volume to the defined anatomic region.

With treatment volumes extending beyond one body cavity, one must use adjoining-field configurations such as mantle and para-aortic fields in Hodgkin's disease. Field junctions require exquisite attention to avoid areas of overdosage and underdosage, which may be associated with local recurrence or unnecessary toxicity.

Optimization of treatment techniques. Since the beginning of radiation therapy a very extensive number of methods, beam modalities and irradiation techniques have been developed. Beside the choice of radiation modality there is a large number of degrees of freedom that can be used for treatment optimization including: beam energy, beam directions, beam collimation, beam profiles and the irradiation

technique in general as determined by the type of equipment used.

Radiation modality. The basis of means of modern radiotherapy is made by gamma therapeutic devices and linear accelerators (fig. 2.4. and 2.5). And, both photon, and electronic radiation in the latter case can be used (fig. 2.6).



Fig. 2.4. The linear accelerator – the basic device for modern radiotherapy.



Fig. 2.5. Cobalt telegammatherapy (apparatus Teratron).

Both photon, and electronic radiation in the latter case can be used ().

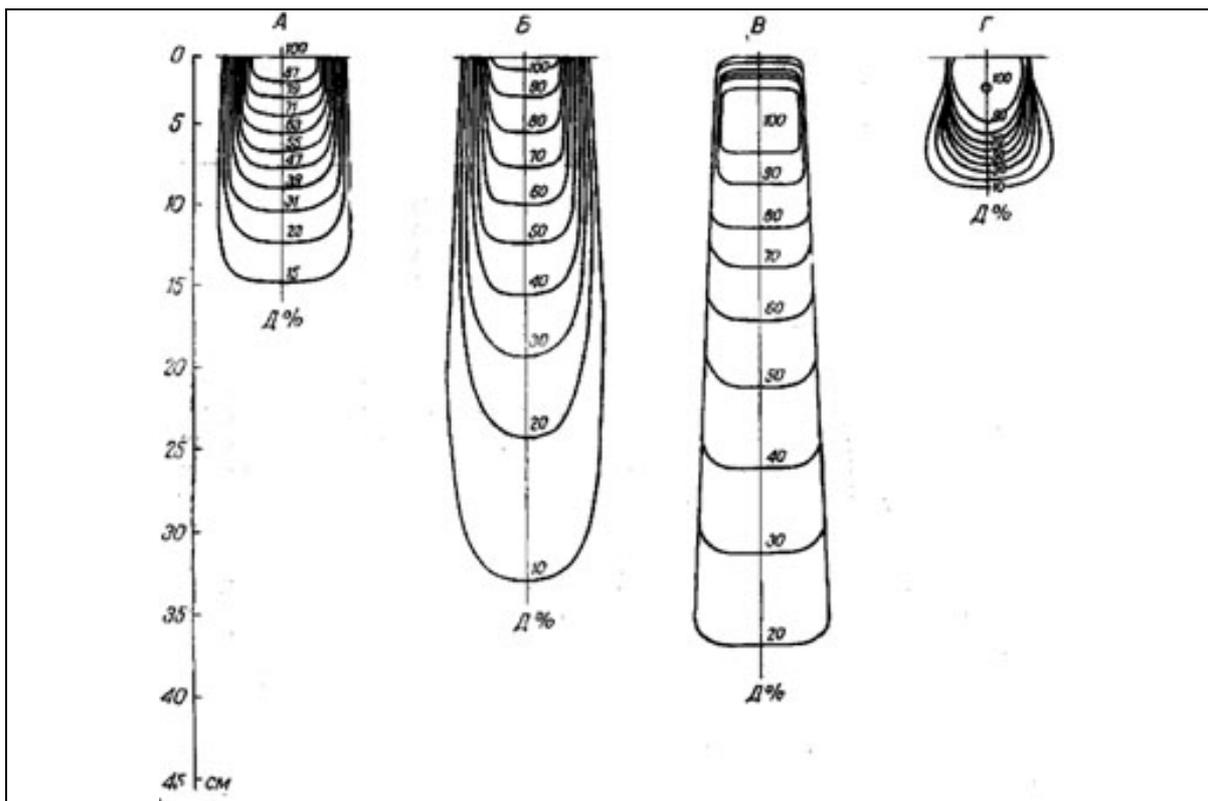


Fig 2.6. The dose distribution in tissue. A – orthovoltage x-rays (250 keV), Б – γ -rays ^{60}Co (1,25 MeV), В – 25 MeV linear-accelerator x-rays, Г – 20 MeV electrons.

During the last decades heavy charged particle therapy with neutrons, protons and heavy ions have been used more extensively too (fig. 2.7). High-energy cyclotrons produce energetic charged particles of potential value in radiation therapy. Protons, for example, yield a discrete volume of increased dose at a depth that varies with the energy of the incident proton beam (fig. 2.8). The dose distribution is characterized by a Bragg peak resulting from relatively dense nuclear reactions as the particle loses velocity. Therapeutically useful proton energies (e.g., 160 MeV) have an RBE only slightly higher than that of photons. Other particles (e.g., high-energy carbon, neon, or argon ions) have a similar dose distribution. In addition, the linear energy transfer (LET) of the latter particles is increased in the region of peak physical dosage, resulting in an even greater biological dose differential at the depth of the Bragg peak. Protons have produced intriguing results in focal intraocular tumors such as choroidal melanoma and in pituitary adenomas.



Fig. 2.7. Radiotherapy by beam of protons at eye tumours.

A further reason for leaving out the heavy high liner energy transfer (LET) particles are that they are not universally applicable. Due to their high ion density the damage to the genome is more severe and generally not repairable.

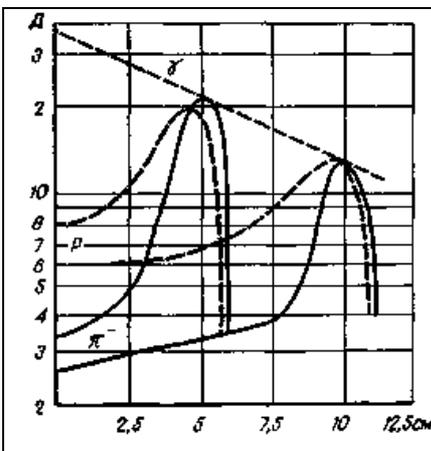


Fig. 2.8. Dose distribution at an irradiation the heavy loaded particles of high energy.
P - an irradiation protons of high energy.

Since the more efficient repair capacity of the normal tissues is one of the corner stones of radiation therapy, high LET radiations are not really suitable for treating often extensive microscopic disease.

2.5. External radiotherapy

Nowadays all methods of external radiotherapy can be conditionally divided into: conventional irradiation, conformal irradiation and intensity-modulated radiation therapy (IMRT), corrected under images (image guided radiation therapy – IGRT).

Conventional radiotherapy is based on use of rather simple techniques of irradiation of patients (formation of fields of irradiation by means of diaphragms with unchangeable degree of ionising radiation absorption, standard lead blocks and wedge-shaped filters). The choice of the centre and field borders in conventional radiotherapy is carried out on the basis of the projective image received under the set corner. For conventional radiotherapy application of two-dimensional planning with use for positioning of the irradiated volume radiography or computer tomography and a x-ray simulator of an irradiation also is characteristic. For dosimetric maintenance water phantoms and the tissue equivalent phantoms are used. Traditional radiotherapy is used till now in clinical practice.

Conformal therapy. Conformal radiotherapy was a following stage of radiotherapy development. In conformal radiotherapy three-dimensional planning of irradiation is necessarily used. The devices which contain x-ray simulators of an irradiation and computer tomography are called a simulator-CT that allows using more exact preparation of the patient for radiotherapy including fields of an irradiation of a compound configuration.

More modern means of definition of the irradiated volume are presented by a CT-simulator, which includes the spiral x-ray computer tomograph providing the three-dimensional image of a tumour and surrounding healthy tissues. At conformal radiotherapy for creation of more exact dose distributions in the irradiated volume various variants of figured blocks are applied.

One of versions of conformal radiotherapy is a gamma knife technology (Lexell Gamma Knife). There are 201 sources of ionising radiation in a gamma knife (^{60}Co with a radioactivity 30 Ci; 1,1 TBq everyone), each placed in a circular array in a heavily shielded assembly (fig. 2.9).

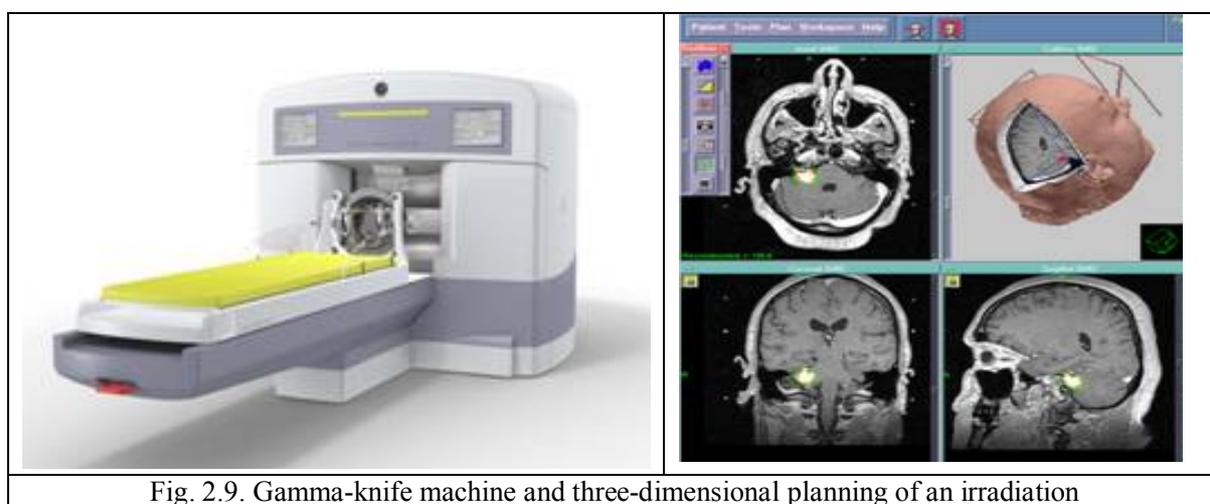


Fig. 2.9. Gamma-knife machine and three-dimensional planning of an irradiation

The gamma knife used to treat brain tumors by administering high-intensity radiation therapy in a manner that concentrates the radiation over a small volume. The device directs gamma radiation through target points in the patient's brain. The patient wears a specialized helmet that is surgically fixed to the skull, so that the brain tumor remains stationary at the target point of the gamma rays. An ablative dose of radiation is directed to a tumor in one treatment session, while surrounding brain tissues are relatively spared. Radiosurgery uses high doses of radiation to kill cancer cells and shrink tumors, delivered precisely to avoid damaging healthy brain tissue. Gamma knife radiosurgery is able to focus accurately many beams of high-intensity gamma radiation to converge on one or more tumors. Each individual beam is of relatively low intensity, so the radiation has little effect on intervening brain tissue and is concentrated only on the tumor itself.

Gamma knife radiosurgery has proven its effectiveness in patients with benign or malignant brain tumors up to 4 centimeters in size, vascular malformations such as an arteriovenous malformation, pain or other functional problems. For treatment of trigeminal neuralgia, the procedure may be used repeatedly on patients. The risks of gamma knife radiosurgery treatment are very low, and complications are related to the condition being treated. Dose distribution generated by sources, is close to the spherical. Radiation from all sources gathers and operates like a noninvasive surgical knife (the dose is unitary brought to the pathological centre till 60-70 Gy, sufficient for destruction of a tumour or obliteration of vascular malformations). Diameter of isodose_spheres is defined by secondary replaceable colimatory in a helmet made of tungsten. Similarly surgery operations, treatment procedure is spent unitary, however thus there are no cuts of a skin and there is no necessity to spend cranial trepanation. Radio surgery is considered to be the most significant achievement in neurosurgery development for last 20 years. Thanks to reliability, accuracy and efficiency the gamma knife is considered to be «a golden standard» in radio surgery.

A following step to development of beam therapy was *intensity-modulated radiation therapy*, IMRT. Additional formation of a bunch is reached by use of multi-leaf collimator (fig.2.10).

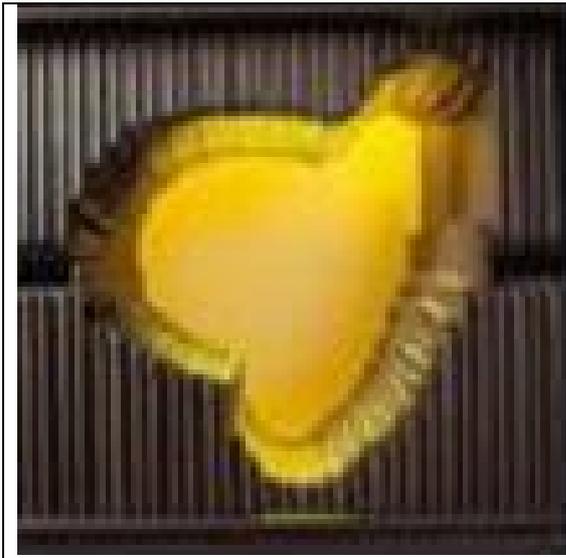


Fig. 2.10. Multi-leaf collimator.

The basic tenet of intensity modulated radiotherapy is that the treatment beams have a non-uniform beam intensity across their profile. Conformal radiotherapy aims to reduce normal tissue dose by shaping the beams to the projection of the tumour, but IMRT goes a step further, enabling much more complex 3D dose distributions to be created by the use of intensity modulated beams. At IMRT continuous adjustment of the form of a therapeutic radiating field in a projection of the planned volume of a target during an irradiation session takes place.

Use IMRT in clinic demands absolutely obligatory maintenance of following conditions:

- presence of the correct image of a primary tumour and the structures surrounding it, received by radiological methods of diagnostics;
- because of possible physiological movement targets (tumour) and organs at risk rigid immobilization of a patient on a medical table of the radiotherapeutic device is necessary.

At IMRT more rigid immobilization, than at conformal and conventional radiotherapy is used. Usually there is a special lath made of carbonic fibres on a table which, in combination with thermoplastic materials, gives the chance to save the same position of the patient during all time of radiotherapy session. (2.11).

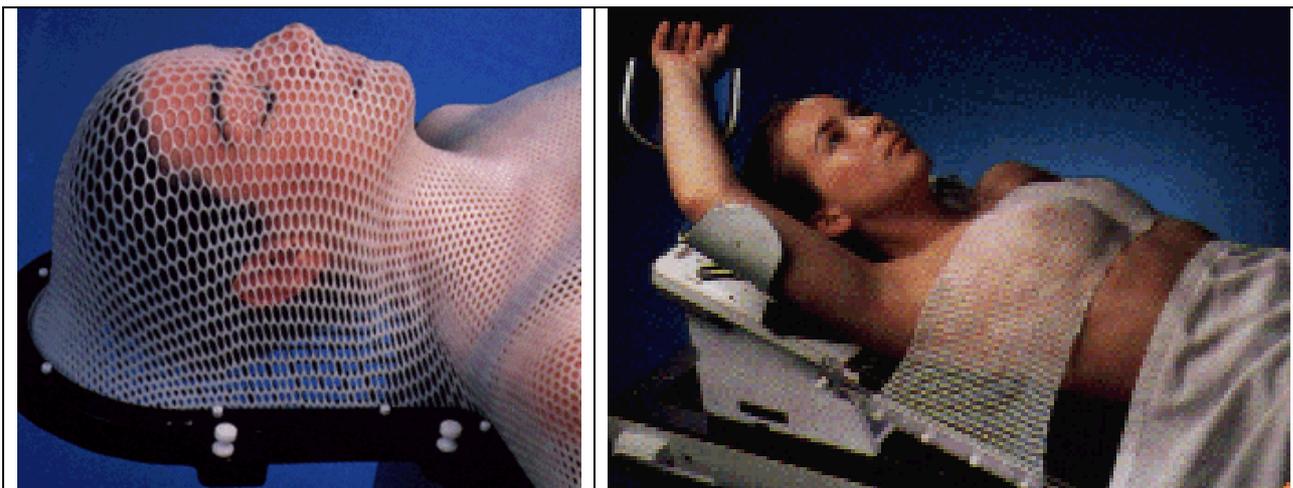


Fig. 2.11. Immobilization devices. The fixing device from special plastic for a head and chest.

In planning of IMRT enough rigidity should be provided according to the recommendations made in reports №50 and №62 ICRU (International Commission Radiation Units and Measurement). In the irradiated volume the concept GTV (gross tumour volume) is applied. GTV is the big tumoral volume, i.e. the tumour is defined by clinical, beam, tool methods. Clinical volume of a target (clinical target volume - CTV), is a zone in which it is necessary to liquidate macro-and microscopic displays of a malignant tumour. CTV includes macroscopical volume of a tumour and tissues in which possibility of microscopic tumoral invasion presents. The planned volume of a target (planning target volume - PTV) represents a zone which takes into consideration shifts of the clinical volume due to change in breath of the patient, body mobility and equipment errors. The planned volume of organs at risk (the-organ-at-risk-OAR) is healthy tissues and the organs getting in the field of ionising radiation influence during radiotherapy.

All listed volumes and skin contours should be represented at all slices used for planning. For the listed structures it is necessary to calculate DVHs (dose volume histograms) - the histogram a dose-volume. Dose distribution should completely correspond to following criteria:

- <5 % from OAR receive <60 % from a planned dose;
- > 95 % PTV receive > 95 % from a planned dose;
- <10 % PTV receive > 120 % from a planned dose.

IMRT provides more selective beam influence on a tumour in comparison with conventional and conformal radiotherapy.

Nowadays the methods of overcoming of problems connected with moving of tumours and organs are rapidly developing. Body parts move both in sessions of

radiotherapy, and between them owing to breath, digestion and small differences in position of the patient during each session of radiotherapy. Such moving can lead to reception of an excessive dose of radiation by the normal tissues surrounding a tumour, and wrong treatment of the tumour.

The radiotherapy corrected under images (image guided radiation therapy - IGRT), provides reception of images of the tumour and surrounding of healthy tissues directly ahead of a session of radiotherapy and during it. These images are used for definition of moving of a tumour and healthy tissues and correction of a direction of a therapeutic bunch of radiation according to the above-stated moving. According to system of respiratory "shutter" which switches on and disconnects a therapeutic bunch of radiation synchronously with breath, it is possible to limit treatment by a part of a respiratory cycle, when the tumour is in the field of a therapeutic bunch and by that to limit the planned volume of an irradiation. It gives the chance to increase the absorbed dose in a tumour and to reduce a dose falling to healthy tissues surrounding it. At this technology cone or fan beams of therapeutic radiation can be used.

The fan bunch of radiation is used in the most modern methods of beam therapy – tomotherapy. Tomotherapy represents the innovative radiotherapeutic method, allowing to realise intensively modulated radiotherapy (IMRT) and radiotherapy with image correction (IGRT). The method is based on a level-by-level irradiation by a fan bunch of photons with modulation of intensity and realised by means of the installation combining in functionality linear accelerator and a spiral computed tomography.

Installation for tomotherapy represents the ring console in which subsystems of the linear accelerator and detectors for a computer tomography (fig. 2.12) are mounted.

Idea is to use a fan beam modulating collimator for "spiral irradiation" much in the same way as used as spiral computed tomography. The patient is then being moved through a continuously rotating modulated fan beam. Installation for tomotherapy represents the ring console in which subsystems of the linear accelerator and detectors for a computer tomography are mounted.

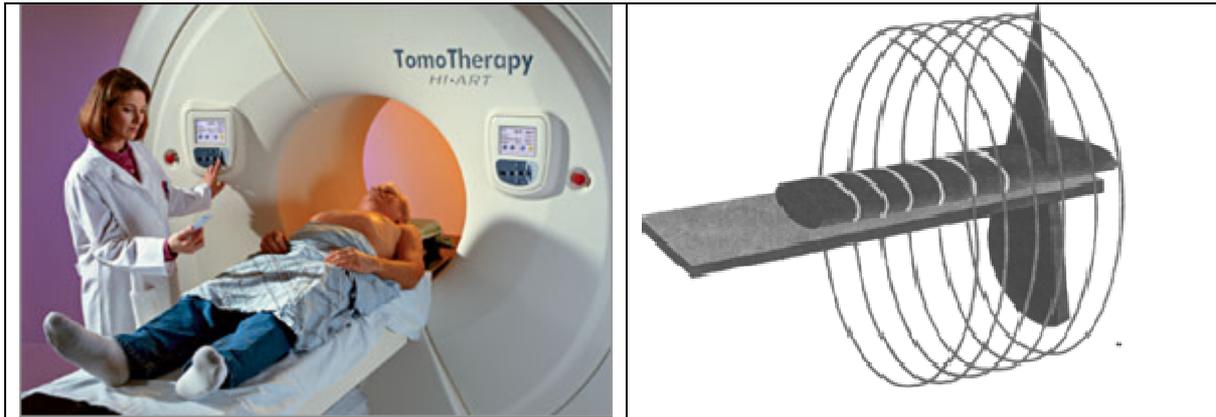


Fig. 2.12. Preparation for a session of radiotherapy on TomoTherapy HI-ART machine; on the right: the schematic image of a principle of a spiral irradiation.

TomoTherapy uses the x-ray with high (MeV) energy, which collimates in a fan bunch with a help of similar fissura multi-leaf collimator. Thus this radiation is used for diagnosing and receiving computer-tomography images as well as with therapeutic purposes. TomoTherapy provides the closed cycle for planning, simulations, leading of the medical absorbed dose and verification of radiotherapy within the limits of one separate device. One of its most important advantages is considerable simplification of conformal therapy in comparison with cone bunches therapy without deterioration of possibilities of formation dose fields. Key component of tomotherapy is four-dimensional representation of a target and surrounding tissues where the fourth dimension is time coordinate which should be considered in a context of change of the specified structures during a medical course. It is considered important, that the computer tomography on megavolt photons represents the information in numbers of Hounsfield, which is necessary for dose calculation. According to these data the analysis of the medical plan is carried out.

Technologies IMRT and IGRT essentially improve results of radiotherapy as give the chance leading considerably more radiation doses, than at conventional treatment.

Variant of IGRT is a kiber-knife (KyberKnife) system in which the special compact linear accelerators are established on the robotised hand supervised by the computer (fig. 2.13). In this technology there is a superfast computer system of irradiation planning in which basis lies the comparison of three-dimensional reconstruction of CT, MRI and PET images. The images of monitoring system define a site of a tumour and corrects a direction of a bunch of photons. By means of the robotised hand of a kiber-knife it is possible to direct irradiation in the centres of the complicated form with the modulation of intensity. The course of radiotherapy thus

consists of one or several fractions. Unlike a gamma knife, a kiber-knife system does not use invasion immobilization and it is possible to direct beam treatment to tumours of backbone channel. The same can be reached at application multi-leaf collimator with steriotaxis prefixes on modern linear accelerators.



2.6. Brachytherapy

A contact irradiation is also named brachytherapy (from Greek «brachys», short). In contact irradiation the basic advantage of radiotherapy is the sharp gradient of a dose in process of removing from a source of radiation that allows to spare normal tissues at an adequate irradiation of a tumour. The dose distribution in brachytherapy is governed largely by the inverse square law. By geometric planning, one can achieve a dose distribution encompassing the desired target volume with far less irradiation of surrounding normal tissues than can be achieved with external-beam irradiation. To assure relative dose homogeneity within the target volume, brachytherapy applications are used primarily for tumors less than 5 cm in the largest diameter.

Nowadays closed and opened radionuclides are applied. Intracavitary and interstitial irradiation (the radiation source is in tissue of a body of the patient) are carried out, consistently entering endo - or intrastat in a cavity or tissue, and then a radiation source on command from a control panel from protected room for radiation action of a premise arrives in endo - or intrastat. During this irradiation procedure the personnel do not present in the room. (fig. 2.14 and 2.15).

The principal types of brachytherapy include intracavitary applications (within body cavities such as the vagina or nasopharynx), interstitial implants (directly into a tissue), and mold applications (adjacent to tumor sites such as skin or eye). Brachytherapy has been used in adults most often for cancers of the female genital tract, upper aerodigestive tract, breast, soft tissues. Pediatric applications have been described more recently, primarily for retinoblastoma and soft-tissue tumors.

The closed source of radiation (the closed radioactive preparation) is the radioactive substance which is concluded in such cover or in



Fig. 2.14. Apparatus for brachytherapy



Fig. 2.15. The container with radioactive sources for brachytherapy.

such physical status which prevents distribution of substance into environment. Being the closed sources they most often use needles and tubules with ^{137}Cs (energy of gamma radiation 0,66 MeV, a half-life period of 30 years) and preparations ^{60}Co (energy of gamma radiation 1,17 and 1,33 MeV, a half-life period 5,26 years). Last

years ^{192}Ir (energy of gamma radiation 0,30-0,61 MeV, a half-life period 74,4 days) is widely used as it possesses a high specific radio-activity, that allows to apply sources of the small sizes.

The preference is given to intracavitary, and to interstitial irradiation with high capacity of a dose. Treatment occupies some minutes and is applied both in the independent plan, and in a combination with remote irradiation.

Current practice most commonly uses ^{192}Ir , an artificially produced radionuclide imbedded in wire or seeds that can be after loaded into hollow silastic tubes. Interstitial placement of the tubes is performed by direct positioning or by stereotactic localization using computed tomographic (CT) guidance. The geometry of the implant can be planned before insertion, confirmed by radiographs during the procedure, and altered if necessary; when it is satisfactory, the tubes are loaded with the radioactive sources. This sequence allows greater accuracy while limiting exposure of medical personnel. The implant remains in place for a calculated period of time, typically 2 to 5 days, and is subsequently removed with little difficulty.

Brachytherapy experience has been well documented in cancer of uterus, rectum, mouth cavity. Recent series document successful applications of both intracavitary and interstitial brachytherapy in soft-tissue sarcomas. Constant implants, basically iodine seeds (^{125}I), are applied first of all for treatment of early forms of prostate cancer as alternative of surgery treatment.

Interstitial radiotherapy is surgical procedure, therefore it should be lead up with observance of the general surgical rules.

System radiotherapy is carried out with radioactive iodine (^{131}I), radioactive strontium (^{89}Sr) and is based on metabolic features of tissues. It gets to the pathological centres (metastases) and realizes radio therapeutic action.

Lowvoltage x-rays radiotherapy. The basic features lowvoltage x-rays radiotherapy are: radiation is generated at voltage no more than 100 kV, a small skin-source length (to 7,5 sm), small fields of an irradiation (to 25 sm²). Spectral distribution of x-ray radiation can be changed with the filters made of aluminium, and also in skin-source length size. Aluminium filters look like plates of various thicknesses and serve for selection of necessary qualitative structure of a beam of radiation at the expense of a long-wave spectrum filtration (fig. 2.16).



Fig. 2.16. Lowvoltage x-rays apparatus (40-100 kV).

In lowvoltage x-ray radiotherapy 50 % of isodose lines are on depth up to 1 sm. In lowvoltage x-ray radiotherapy intensity of radiation and, accordingly, a dose sharply reduces at furthers distances from skin. Nowadays lowvoltage x-ray radiotherapy is widely used as an independent method of treatment of benign and malignant tumours of skin and, less often, as a component cancer treatment of oral cavity, a rectum.

Contra-indications for lowvoltage x-ray radiotherapy:

1. Deep skin lesions (cancer in scars after burns, lupuses, syphilis, relapse of skin cancer after beam therapy).
2. Lesion is deeper than 12 mm; external methods of irradiation are more preferable.

2.7. Structure of a radiotherapy course

The prebeam period. During the prebeam period preparation to treatment is carried out. It should begin with psychological preparation.

Necessity of radiation influence is explained to a patient, its efficiency specifies possible changes in the state of health and some radiation reactions as well as a diet pequiliarities.

The next important phase is clinical topometry. The prebeam period ends with finalization of a medical plan. The beam plan is a set of documents of the radio biological and dosimetric planning, including a map of dose distributions in a patient's body and the radiographies made through entrance fields and proving the correct direction of a radiation bunch to the centre.

From a mathematical point of view classical radiation therapy planning has been treated as a forward process as it tries to answer the question: how will the absorbed dose in the target volume and surrounding normal tissues be distributed for a given target volume, associated patient geometry and suggested configuration of the incident beams? Classical radiation therapy optimization is therefore generally a trial and error process, where gradually improved dose plans can be found by trying out an increasing number of beam configurations.

However, in mathematical terminology radiation therapy planning is fundamentally an inverse problem. This is so, because what we really want to find, is the optimum combination of incident beams for a given target volume. More exactly, the planning process should answer the question: which configuration and shape of the incident beams is best for controlling the tumor growth with minimal damage to normal tissues? At least under the assumption that the desired dose to the target volume or the geometrical and radiobiological properties of the tumor and normal tissues of the patient are known, it should be possible to find the optimal irradiation technique (fig. 3.17).



Fig. 3.17. 3-D planning.

The question mark indicates the principal quantity calculated, the isodose distribution in the patient and the optimal incident beam profiles. Obviously the absorbed dose distribution in the patient is also obtained by the inverse calculation either by an ordinary forward calculation or by the inversion method itself.

So, to make a treatment program for each patient it is necessary to define sequentially:

1. The treatment purpose.
2. To solve a question on a single and total dose.
3. To choose a method of irradiation and ionising radiation source.
4. To define conditions of irradiation: number and sizes of fields, a direction of the central bunches of beams.

The beam period. The beam period is the period of performing irradiation under constant medical supervision over the patient. For irradiation of each field a patient should take comfortable position. It is crucially important to immobilize patients.

In the course of irradiation the doctor or the nurse observes the patient using a TV screen. Intercoms provide communication of the doctor and the patient. Upon

termination of irradiation the patient is recommended to have a two-hour-rest on fresh air or in a chamber with good ventilation. Data on each irradiation session are registered in a protocol.

The postbeam period. In the postbeam period, even in absence of clinically defined signs of a radiation injury, there is a decrease in tolerance of the irradiated healthy tissues to additional injuring influences. Therefore patients are recommended to avoid physical and chemical traumas of irradiated zones. Intensive ultra-violet irradiation, general thermal, physiotherapeutic procedures are absolutely counter-indicated to oncological patients, irrespective of term and irradiation area. In the postbeam period rehabilitation actions are of great value.

CHAPTER 3. PRINCIPLES AND METHODS OF RADIOLOGY

3.1. The general principles of visualisation of medical images

Nowadays 60 - 80 % of all initial diagnoses are made by means of radiology methods of research.

Most widely electromagnetic radiation is used for visualisation of anatomical structures which are opaque and inaccessible for direct supervision. Now electromagnetic radiation is known with length of a wave from ten billionth of a millimetre to hundreds of kilometres.

The wide area of electromagnetic radiation (0,001-10 nanometers) belongs to X-rays.

At present in medicine about 90 % of all visualised images are received by means of X-rays. The electromagnetic ionising radiation created by radioactive substances is called gamma radiation. Radioisotope diagnostics which is based on visualisation of the images formed in gamma-rays of radionuclides is widely applied in functional researches, diagnostics of some diseases.

Resonant effects observed in substance (nuclear magnetic resonance) have a lot of benefits.

Acoustic imaging is widely used in medicine. It is a range of methods and techniques of optical imaging of the ultrasonic field appearing after interaction of elastic acoustic waves and the object. Ultrasound is identical to radio region in wave periods from 1 mm to 10 km.

Any image becomes meaningful after it is analysed by visual system and interpreted on the basis of data on character of the interaction of a physical field and the investigated object (fig. 3.1).

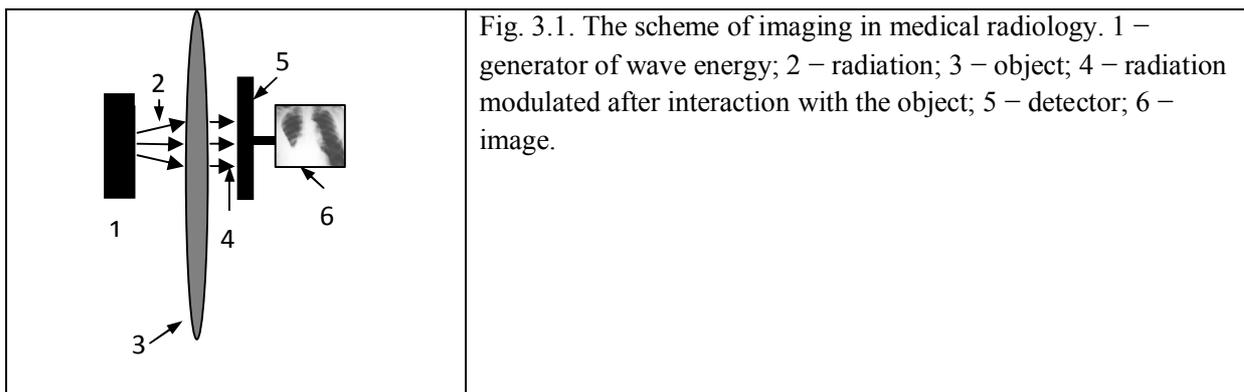


Fig. 3.1. The scheme of imaging in medical radiology. 1 – generator of wave energy; 2 – radiation; 3 – object; 4 – radiation modulated after interaction with the object; 5 – detector; 6 – image.

Investigated object modulating parameters of a visualised physical field imaging system and visual analyser (doctor's, operator's) participate in visualisation and analysis of received images. This scheme does not correspond to radionuclide imaging when the gamma-ray source (radionuclides) is inside the human body.

The penetrating reflection or radiation emitted by the investigated object is modulated in one or several parameters by properties of the investigated object and it contains certain information about it. Spatial distribution of radiation field of the object is converted by the visualizer into similar spatial distribution of luminous flux, brightness or colour of which varies from element to element of the image depending on the object modulated field parameters.

In beam images the morphological information is mostly presented. For example, the x-ray picture of thorax in most cases gives the information about an anatomic structure of human organs. However some images contain the information on a physiological status of human organs. So, if the patient inhales air containing radionuclide ^{133}Xe , variations of radionuclide distribution in lungs will give the information on spatial characteristics of an air stream in lungs. The distribution mentioned can be visualised by means of gamma radiation emitted by ^{133}Xe .

There are analogue and digital images in radiology.

Analogue images contain the information of continuous nature, for example, conventional radiographs.

Digital images are received by computers. They have cellular structure (matrix). All digital technologies and techniques at the initial stage are analogue. Degree of radiopacity on x-ray film, light intensity on the fluorescent screen, electric current in detectors of x-ray computed tomographic scanner, of radiodiagnostic device, ultrasonic device, receiver coil of MR-imager are all analogue reciprocal information. The analogue information mentioned above converts into digital by means of special devices (analogue-to-digital converters). The digital image appears

on the display. It can be transformed into the analogue image by digital-to-analogue converters.

3.2. X-rays methods of research

Wilhelm Conrad Roentgen, a Dutch physicist, discovered a form of radiation that now bears his name, the roentgen ray, in 1895. He called this new form of unknown radiation, which was invisible, which could penetrate into objects and cause fluorescence "X-strahlung" (x-rays) because initially he did not understand its nature. This name did not change in his native land and in the West countries. It was not long before a new medical speciality, radiology, emerged.

The main properties of X-rays:

1. X-rays, proceeding from focus of x-ray tube, propagate in straight lines.
2. They do not deviate in electromagnetic field.
3. Propagation speed is equal to the speed of light.
4. X-rays are invisible, but, being absorbed by some substances, they make them glow. This glow is called fluorescence, it is the basis of roentgenoscopy.
5. X-rays have photochemical effect. This property of X-rays is the basis of radiography.
6. X-ray radiation has ionising effect, and enables the air to conduct an electric current. Neither visible, nor thermal, nor radio waves can cause this phenomenon. Based on this property x-ray radiation, as well as radiation of radioactive substances, is called as an ionising radiation.
7. Another important property of X-rays is their penetration ability, i.e. ability to pass through bodies and objects. Penetration ability of X-rays depends on:
 - quality of beams. The shorter X-rays are (i.e. the more rigid x-ray radiation is), the deeper these beams penetrate and, vice versa, the longer x-ray wave is (the softer radiation is), the more shallow they penetrate;
 - volume of an investigated body: the thicker the object is, the more difficult is for X-rays to move through it.
 - chemical composition and structure of an investigated body. The more atoms of elements with high atomic weight and atomic number (in the periodic table) in the substance exposed to X-rays, the more it absorbs X-ray radiation and, vice versa, the less nuclear weight is, the more transparent substance to these rays is. The explanation for this phenomenon is that in electromagnetic radiation with very small wave length, which X-rays are, high energy is concentrated.
8. X-rays have active biological effect. DNA and cells membranes are critical structures.
9. X-rays complies with the inverse square law, i.e. intensity of X-rays is inversely proportional to squared distance.

Gamma rays have the same properties, but these types of radiation differ in a way of their formation: X-ray radiation is obtained on high-voltage electric installations, while gamma radiation is obtained as a result of nuclear decay.

Methods of X-ray examination are divided into basic, special and particular methods.

The basic radiological methods. The basic methods of radiological research are: radiography, roentgenoscopy, X-ray computed tomography.

Radiography and fluoroscopy are carried out by X-ray machines (fig.3.2).

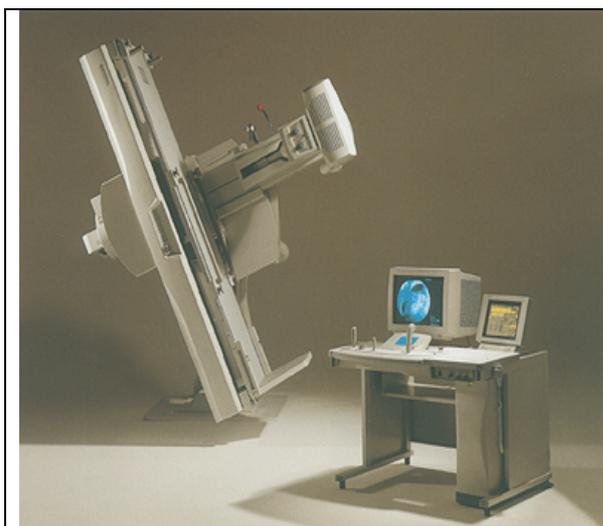


Fig. 3.2. Modern X-ray machine.

The basic elements of X-ray machines are: feeding device, an X-ray tube, device for X-ray radiation formation and radiation detector. The X-ray machine receive an alternating current from a city network. The feeding device raises voltage up to 40-150 kV and reduces pulsation; in some devices current is almost direct. Quality of X-ray radiation as well as its penetrating power depends on voltage. As the voltage increases, radiant energy increases too. Thus wave length decreases and penetrating power of radiation received increases.

The X-ray tube is an electronic device transforming electric energy into X-ray energy. Cathode and the anode are important elements of the tube.

When applying low voltage current to the cathode filament heats up and starts to emit free electrons, forming an electronic cloud around the filament. Electrons emitted by the cathode accelerate in electric field between cathode and anode, fly from cathode to anode and, hitting against anode surface, slow down producing X-ray quanta. To reduce the influence of radiation on radiographs quality Bucky diaphragm is used.

Receivers of X-ray radiation are: X-ray film, fluorescent screen, digital radiography systems, and dosimetric detectors (in CT).

Imaging is a result of X-rays attenuation by the material through which they penetrate. The denser the structure is, the greater the attenuation is, and as a result there is less blackening of the film as fewer X-rays strike the film. Less dense structures attenuate the beam to a lesser degree and this results in a greater blackening of the film as more X-rays strike it (fig. 3.3).

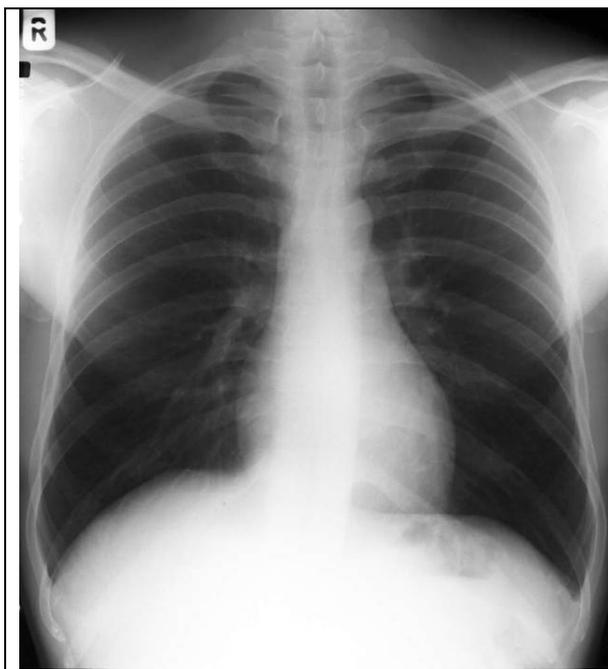


Fig. 3.3. Chest radiograph in frontal projection.

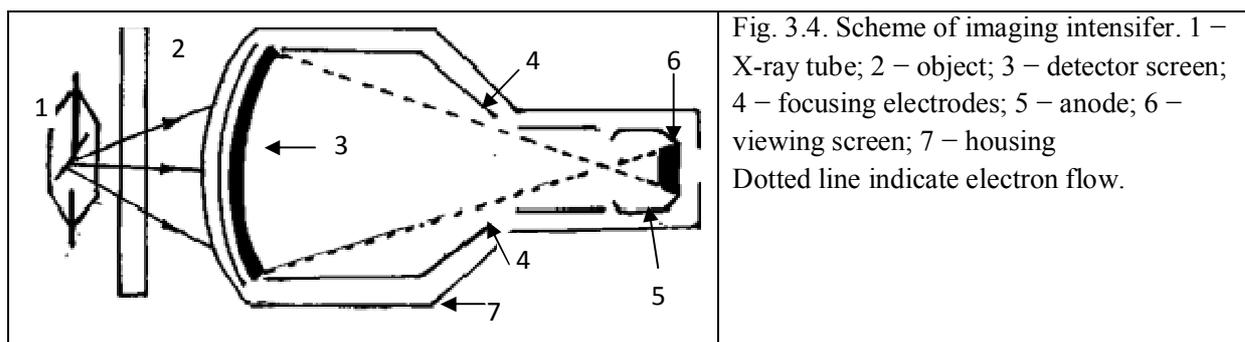
Radiographic density is a term that refers to the degree of blackness of a film. Radiographic contrast is the difference in radiographic densities on a film. The radiographic density of a substance is related to its physical density. Structures that produce more blackening on film are referred to as being radiolucent; those that produce less blackening are called radiopaque or radiodense. There are four types of radiographic densities; these are (in increasing order of physical density): gas (air), fat, water, and bone (metal). Radiographically these appear as black, gray-black, gray, and white, respectively.

The most common type of recording media is X-ray film. X-ray film consists of a plastic sheet coated with a thin emulsion that contains silver bromide and a small amount of silver iodide. This emulsion is sensitive to light and radiation. A protective coating covers the emulsion. Light or ionizing radiation produces chemical changes within the emulsion, resulting in the deposition of metallic silver, which is black. The

amount of blackening in a film is dependent entirely upon the amount of radiation reaching the film and, therefore, on the amount attenuated from the beam by the subject.

Other recording media include the fluoroscopic screen/image intensification system, photoelectric detector crystals, xenon detector systems, and computer-linked detectors that measure actual attenuation. These last detectors are linked to magnetic tape or disks in the computer.

A fluoroscopic screen is a screen coated with a substance (phosphor) that gives off visible light (or "fluoresces") when it is irradiated. The brightness of the light is proportional to the intensity of the x-ray beam striking the plate and depends on the amount of radiation removed from the beam by the object irradiated. In its most common use today, the fluorescent screen is combined with an electronic device that converts the visible light into an electron stream that amplifies the image (makes it brighter) by converting the electron pattern back into visible light (fig. 3.4).



X-ray computed tomography (CT). Creation of X-ray computed tomography became the major event in radiology. For the development and clinical testing of computed tomography Cormack (USA) and Hounsfield (England) shared the 1979 Nobel Prize.

CT enables to study position, form, sizes and structure of different organs, and also their interrelation relations with other organs and tissues. The advancements in diagnostics of different diseases reached by CT challenged fast technical development of devices and significant increasing of their types.

CT registration is based on X-ray recording performed by sensitive dosimetric detectors and X-ray imaging of organs and tissues by computers. The principle of the method is that after beams move through patient's body they get to the detectors in which electric impulses arise. After amplification they are transmitted in the

computer where they are reconstructed according to a special algorithm and create an image of the investigated object. (fig. 3.5, 3.6).

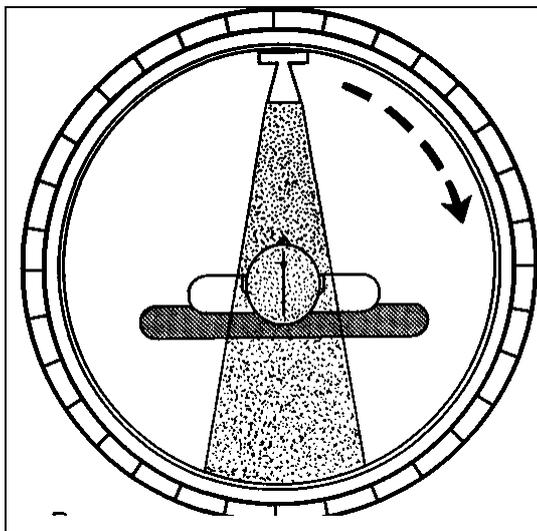


Fig. 3.5. Computed tomography.

In modern CT scanners the x-ray tube rotates within the gantry. Instead of film, detectors measure the amount of radiation removed from the x-ray beam and using a computer for imaging.

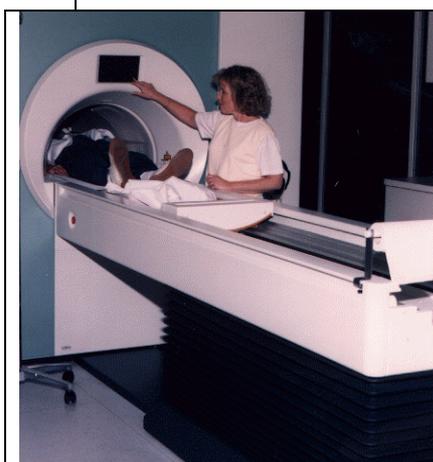


Fig. 3.6. Computed tomography scanner.

Computed tomography (CT) is a planar, transaxial imaging method providing excellent contrast resolution. Computed tomography (CT scanning) can define alterations in soft tissue and bone that are undetectable with conventional radiography because of its cross-sectional display, excellent contrast resolution, and ability to measure specific attenuation values. CT images are produced in computers that enable reformation of transaxial data in the coronal or sagittal plane and three-dimensional analysis of image data. In step-by-step and spiral CT-scanners one or two types of detectors are used. Multislice CTs are supplied with 4, 8, 16, 32 and even 128 lines of detectors. In multislice devices time of scanning is considerably less and spatial resolution in axial direction is better. They enable to obtain information with the help

of high resolution techniques. Quality of multiplanar and volume reconstruction improves considerably. (fig. 3.7, 3.8, 3.9).

Attenuation number is a number used to denote the attenuation coefficient obtained in an X-ray computed tomography (CT) reconstruction. At present it is accepted the representation that uses a scale in which air is assigned a value of 1000 and water has a value of 0. Depending on its density, bone has values between 1000 and 3 000. The values are measured in Hounsfield units (HU).

The minimum size of a tumour or other pathological centre defined by means of CT, differs from 0,5 to 1 cm provided that HU the tissue affected differs from that healthy one in 10 - 15 units.

Disadvantage of CT is the increase of irradiation dose in patients. Nowadays 40 % from the collective dose received by patients at radiology researches falls on CT whereas this research makes up only 4 % from the number of all important radiological researches.

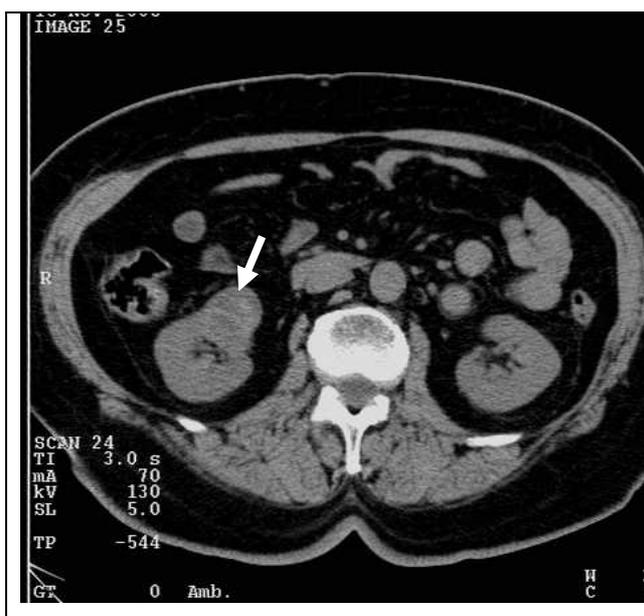


Fig. 3.7. CT-imaging. Computer tomogram of an abdomen cavity at level L2 vertebrae. The right kidney is enlarged, its contours rough (arrow). Renal cell carcinoma.

Both in CT, and at other x-ray researches there is a necessity of application for increase in resolution of a technique of "contrast enhancement". *Methods of radiological research are called special if it is used contrast agents.* Organs and human body tissues become distinguishable if they absorb X-rays in various degree. In physiological conditions such differentiation is possible only in the presence of natural contrast which is caused by a difference in density (a chemical compound of these bodies), size, position. The bone structure against soft tissues, heart and large

vessels against an air pulmonary tissue well comes to light, however chambers of heart in the conditions of natural contrast cannot be allocated separately, as well as organs of an abdomen, for example.



Fig. 3.8. The x-ray computer tomogram of a brain. A hemorrhage in left hemisphere and ventricles of a brain, forming hyperdensity zones (arrow).

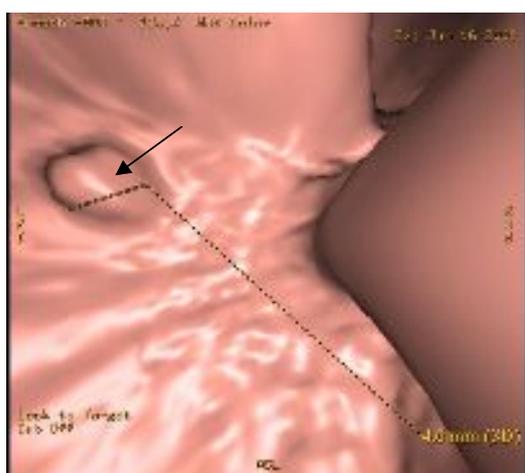


Fig. 3.9. Helical CT of a large bowel (virtual colonoscopy). Diverticulum of a large bowel in the size of 4,6 mm (arrow).

Necessity of studying by X-rays of organs and the systems having identical density, has led to creation of a technique of contrast enhancement. The essence of this technique is in introduction of contrast agents into an investigated organ, i.e. the substances having density, differing from density of organ and his environment (fig. 3.10).

Contrast agents for x-ray researches (CA) can be subdivided into substances with high nuclear weight (positive contrast agents) and low (negative contrast agents). Contrast substances should be harmless.

The contrast substances intensively absorbing X-rays (positive contrast agents):

1. Suspensions of salts of heavy metals - the barium sulfate applied to research GIT (it is not absorbed and is removed through natural ways).

2. Water solutions of organic compounds of iodine which are injected into a vascular channel, get to all organs with a blood current; besides vascular channel contrast enhancement they enable contrast studies of other systems, e.g. of urinary tract, bile duct etc.
3. Oil solutions of organic compounds of iodine, e.g. iodolipol, etc. which are injected into fistulas and lymphatic vessels.

The common chemical structure of all water soluble contrast media is triiodobenzoic acid. These agents are referred to as ionic media because of their property in solution to dissociate into the sodium or meglumine cation and their iodine-containing anion.

These agents are very hypertonic (three times that of serum), resulting in a fluid shift from the intra- or extracellular to the intravascular space or lumen of the GI tract (depending on the route of administration). Although normal individuals may not suffer from any severe long-lasting effects after this shift, patients who are dehydrated or in a precarious state of cardiac and fluid balance are at special risk, particularly for renal failure. Secondary effects from the changes in viscosity and tonicity of the blood include platelet aggregation, changes in blood pressure, change in cardiac output, and changes in pulse rate. As the serum osmolality rises, there may be changes in blood coagulation, with a resultant bleeding tendency.



Fig. 3.10. Contrast enhancement of urinary ways: intravenous urography.

Rapid injection, high-volume injection, and high tonicity and viscosity of the agent are associated with more severe reactions. Occasionally a vagal reaction occurs

where there is vasodilation and systemic hypotension. Bradycardia is encountered rather more than tachycardia.

In kidneys, especially in a dehydrated patient, glomerular and tubular damage may result in temporary impairment of renal function and oliguria.

The goal of reducing the normal physiologic and abnormal adverse effects of the ionic contrast agents led to the development of a new class of water-soluble media. These agents are of two types. The first one includes nonionic monomers (variants of triiodobenzene) in which the sodium or meglumine cation has been replaced by a side chain that will not dissociate from the iodine-containing portion of the molecule. This results in a pronounced lower osmolality than the ionic agents.

The second class of low-osmolality agents is an ionic dimer formed by linking two triiodobenzoic acid molecules, one of which contains a sodium or meglumine cation. However, doubling the iodine content in the anionic portion reduces the overall osmolality.

These new lower osmolality contrast media are associated with a lower overall incidence of side effects and mortality in comparison with the older ionic agents, and now are used in greater frequency than their ionic counterparts. The main reason for their less than universal adoption is the higher cost (approximately 10 times greater) of the low-osmolality agents. Hopefully, this should change in the future.

In addition to their use in angiography, urography, myelography, and arthrography, these same agents may be injected into sinus tracts or used in diluted form to examine the GIT when there is a suspected perforation. They do not cause any of the undesirable side effects that barium is known to produce when outside the GIT. However, there is one important contraindication for water-soluble contrast media: suspected communication between GIT and the tracheobronchial tree (tracheo-esophageal fistula).

Excretion of these agents is by pure glomerular filtration within the kidney. The material is removed intact by the glomeruli. In patients with chronic renal failure, however, the material may be secreted into the bile or small bowel by a process known as "vicarious excretion."

Contrast examination. The most common contrast material used for gastrointestinal examinations is a preparation of barium sulfate mixed with other agents to produce a uniform suspension. These products are available as premixed powders or liquids. They may be administered alone or in combination with air, water, or an effervescent mixture that produces carbon dioxide. These gas-enhanced

studies are referred to as "air contrast" studies. Administration of these preparations is either by mouth (antegrade) or by rectum (retrograde).

In addition to barium preparations, water-soluble agents are available for studying the gastrointestinal tract whenever there is a possibility of leakage of the contrast material beyond the bowel wall. Although barium is a chemically inert substance, it produces a severe desmoplastic reaction in tissues. Water-soluble agents, on the other hand, do not produce this type of reaction and are absorbed from the rupture site to be excreted through the kidneys. The water-soluble agents, however, are not without hazard, since they can cause a severe chemical pneumonia if aspirated. Water-soluble agents also cost more and hence are not used on a routine basis.

Gallbladder studies are performed by oral-administration drugs that are removed from the bloodstream, conjugated by the liver, excreted in the bile, and transported to the gallbladder, where concentration takes place. This results in visualization of this structure.

Urography is the radiographic study of the urinary tract. The contrast agents used for this study are primarily the ionic water-soluble salts of diatrizoic or iothalamic acids or the nonionic agents (iopamidol, iohexol). The common term for this study is the intravenous urogram (IVU). An older and less appropriate term is intravenous pyelogram (IVP). The physiology of these agents will be discussed in the next chapter.

Angiography is the study of the vascular system. Water-soluble agents similar to those used for urography are injected either intraarterially or intravenously, and a rapid sequence exposure is made to follow the course of the contrast material through the blood vessels.

The lymphatic system may be studied by injecting an iodinated form of poppy seed oil into the lymph vessels on the dorsum of the foot or the hand. The resultant study shows the flow of lymph from the limb to the regional lymph nodes and then to the deep lymphatic system. These studies are infrequently used today to stage patients with malignancies. They have been largely superseded by computerized tomography.

A fistulogram involves the injection of contrast material through an abnormal sinus tract into the body. Water-soluble agents are commonly used for these studies. In evaluating an empyema cavity in the chest where there is a danger that a bronchopleural fistula may be present, an oil-soluble material such as Dionosil is used because water-soluble contrast material entering the bronchial tree can produce a severe and often fatal chemical pneumonia.

Diseases affecting the spinal canal may be studied by myelography. The main indication is evidence of cord or nerve root compression. The most common

lesion is a herniated nucleus pulposus from a lumbar disc. Myelography is performed by inserting a needle between the spinous processes of a lumbar vertebra and entering the subarachnoid space. It may also be performed by puncture of the cisterna magna when there is a complete block within the vertebral canal and it is necessary to inject contrast medium above the lesion. Cerebrospinal fluid may be removed for study at this time. Nonionic, iodinated, water-soluble compounds are injected under fluoroscopic monitoring in varying amounts, and the patient is positioned for the study. Myelography is often combined with computerized tomography. The development of magnetic resonance imaging, however, has decreased the number of myelograms performed today, as compared with a decade ago.

All radiological offices where intravascular contrast enhancement researches are performed, should have the tools, devices and medicines necessary for rendering of urgent medical aid.

Premidication with the use of antihistamines and glucocorticoids is expedient as a preventive measure before radiographic contrast study; also a test is carried out for prediction of patient's hypersensitivity to contrast agents. The most appropriate tests are: determination of histamine release from basophils of peripheral blood when mixing it with contrast agents; determination of total complement activity in serum of the patients, who were prescribed radiographic contrast study; selection of patients for premedication by determining the levels of serum immunoglobulins.

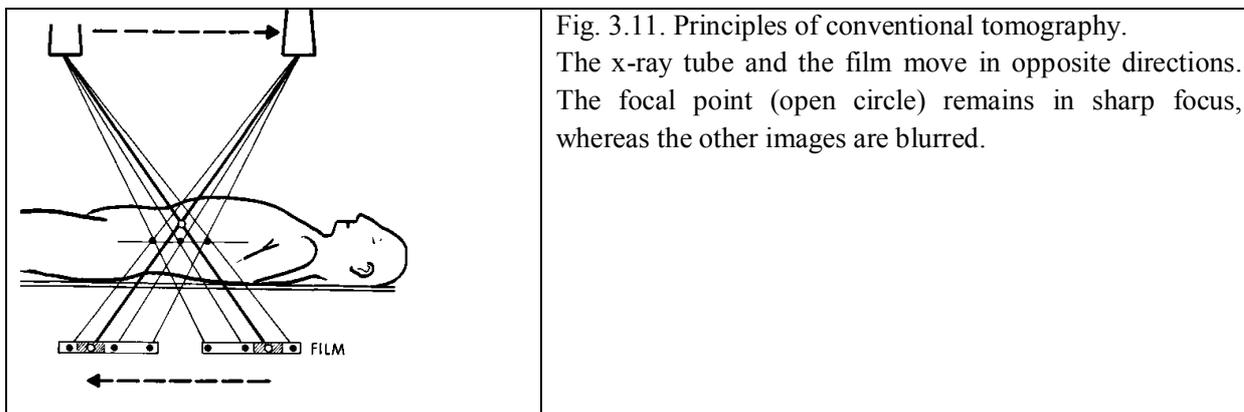
Less frequent complications are "water" intoxication after irrigoscopy in children with megacolon and vascular air (or fat) embolism.

The symptoms of "water" intoxication, when considerable quantity of water is quickly soaked up through bowel walls in a blood channel which unbalances electrolytes and plasma proteins, are tachycardia, cyanosis, vomiting, respiratory impairment with cardiac arrest; the patient can die. Thus, first aid includes intravenous injection of blood or plasma. Prevention of complications in children is irrigoscopy with barium suspension in an isotonic solution of salt, instead of a water suspension.

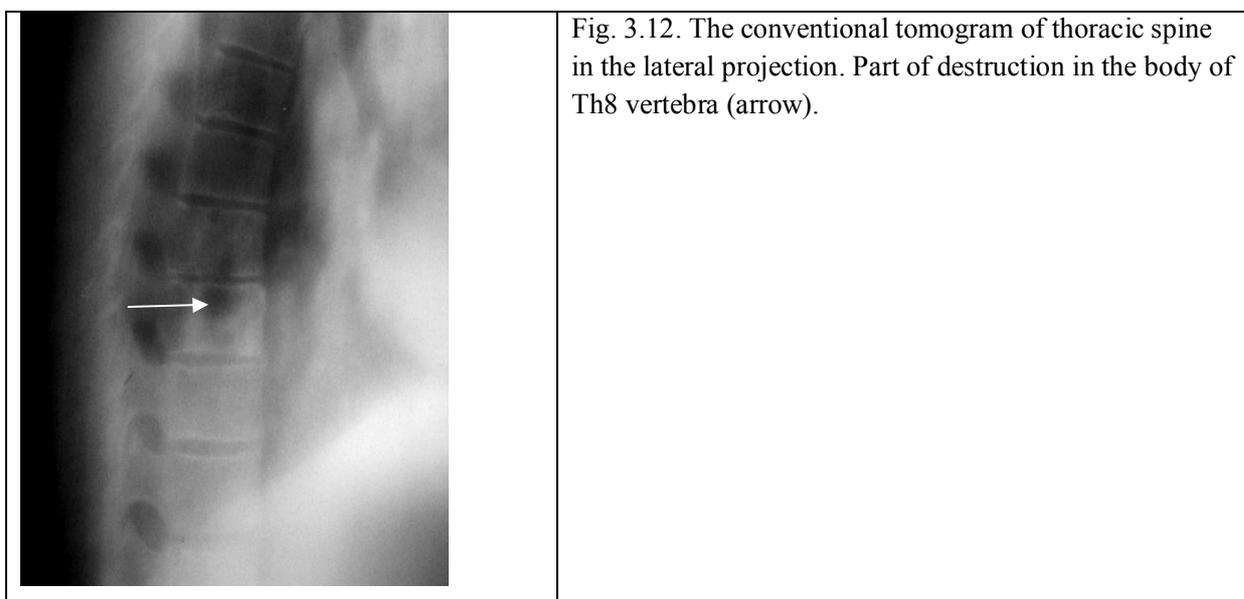
Symptoms of vascular embolism include difficulty in breathing, dyspnea, cyanosis, bradycardia and blood pressure drop, spasms, respiratory arrest. Thus it is necessary immediately to stop injecting the contrast agent, to lay the patient in Trendelenburg position, to start artificial respiration and external cardiac massage, to inject 0,5 ml of 0,1 % adrenaline solution intravenously. It is also important to call the

intensive care brigade for possible intubation of trachea, mechanical ventilation and further medical steps.

Particular methods of X-ray examination. Linear tomography is designed to eliminate summational character of X-ray image. In tomographs the X-ray tube and film (fig. 3.11) move in opposite directions.



During the motion of tube and film in opposite directions, pivot of tube movement is formed. It is a layer which remains as if fixed, and on the tomogram details of this layer are displayed in the form of sharp-outlined shade; tissues above and below the pivot appear to be smeared and are not detected on the image of this layer (fig. 3.12).



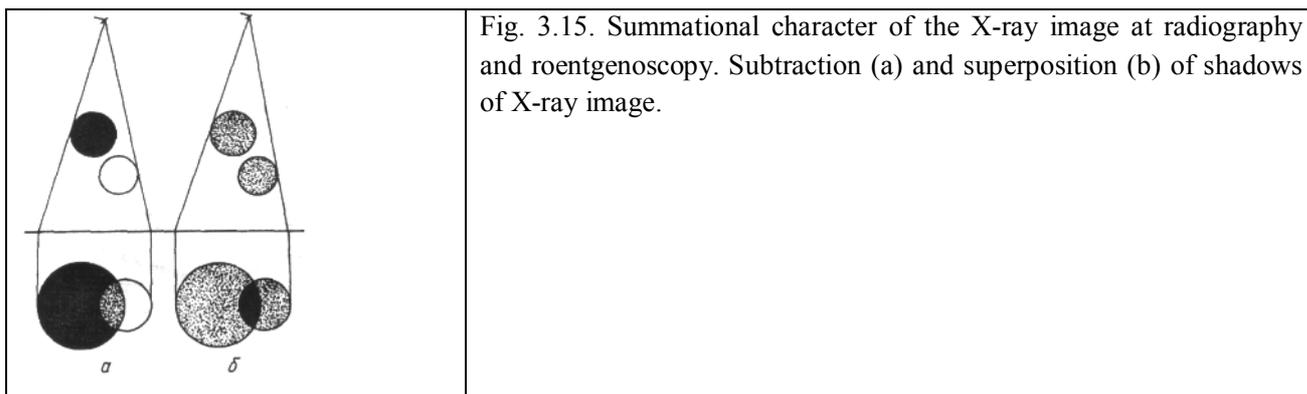
Interventional radiology or invasive radiology is the subspecialty of diagnostic radiology in which diagnostic examinations are performed by

percutaneous puncture. It is also known as interventional or surgical radiology. This subspecialty is the most labor intensive in diagnostic radiology and includes biopsy procedures, percutaneous puncture, decompression and drainage procedures, balloon dilations (angioplastic procedures), extraction techniques, vascular chemotherapy, vascular embolism.

Ultimately, subject of X-ray researches is the shadow image. Features of the X-ray shadow image include:

1. The image consisting of many dark and light areas; according to areas of unequal attenuation of X-ray in different parts of the object.
2. The sizes of X-ray image are always increased (except CT) if compared with object of study and the bigger distance between the object and a film is and the lesser focal length is (distance between a film and focus of X-ray tube), the bigger the image is. (fig. 3.13).
3. When the object and the film are not in parallel planes, then the image becomes distorted (fig. 3.14).
4. The image has summational character (except tomography) (fig. 1.15). Hence, X-ray pictures should be made not less, than in two mutually perpendicular projections.
5. Negative image at radiography and CT.

	<p>Fig. 3.13. Dependence of the sizes of the x-ray image (a, b, c) on distance between an X-ray tube, object and the receiver of the X-ray image (screen, film).</p>
	<p>Fig. 3.14. Change of the object form depending on direction of X-rays (a) and position of the X-ray receiver (b).</p>



3.3. Nuclear medicine

Nuclear medicine traditionally has two divisions, nuclear imaging (radiology) and laboratory analysis. The diagnostic radiologist is the person concerned with the imaging aspect.

The principles of nuclear imaging depend on the selective uptake of certain compounds by different organs of the body. These compounds may be labeled with a radioactive substance of sufficient energy level to allow detection outside the body. The ideal isotope is one that may be administered in low doses, is nontoxic, has a short half-life, is readily incorporated into "physiologic" compounds, and is relatively inexpensive. At the present time, technetium-99m (^{99m}Tc) fulfills most of these requirements.

The half-life of an element is the time necessary for its degradation to one-half of its original activity. There are actually three types of half-lives: physical, biologic, and effective. The physical half-life is that time period in which the element would "decay" on its own. This occurs naturally whether the element is staying on the laboratory shelf or has been administered to a patient. Biologic half-life concerns the normal physiologic removal of the substance to which the isotope has been attached. For example, the sodium pertechnetate, commonly injected for nuclear scanning, is excreted in the urine and into the gastrointestinal tract. Although the physical half-life of technetium-99m is approximately 6 hours, the biologic half-life is less. The effective half-life is a mathematical derivation based on a formula combining biologic and physical half-lives. It measures the actual time the isotope remains effective within the body.

Nuclear imaging is performed on either a static or dynamic basis. Static studies include the thyroid, skeleton, and renal scans. Dynamic studies include e.g. perfusion-diffusion studies of the lung, renal and liver scans. The gamma camera

represents the basic nuclear medical device allowing to visualise radionuclide distribution in organs. Static scintigraphy (fig. 3.16) investigates distribution and accumulation of radiopharmaceuticals (RP) in object of study. Dynamic scintigraphy (fig. 3.17) investigates distribution of RP and time characteristics of accumulation and excretion of radiopharmaceuticals in object of study. Parts with higher accumulation of radiopharmaceuticals on scintigrams are called hyperfixation ("hot"), and parts with the lower accumulation – hypofixation ("cold").



Fig. 3.16. Radionuclide bone imaging (osteoscintigraphy), with ^{99m}Tc -phosphonates. Hyperfixing in left 12 rib. Sign of metastasis of a malignant tumour in the 12 rib on the left.

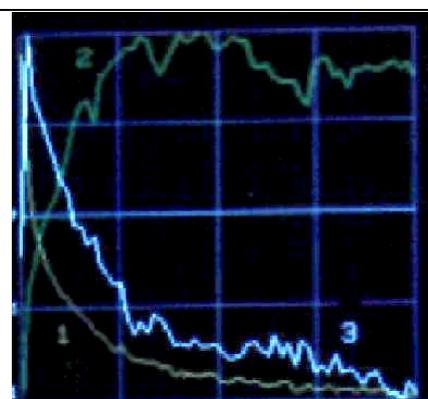
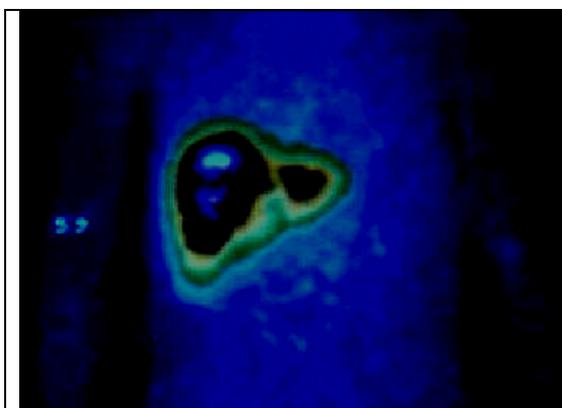


Fig. 3.17. Dynamic scintigraphy of a liver with ^{99m}Tc -labeled imidodiacetic acid. Histogram: 1 - heart area; 2 - liver area; 3 - area of a small bowel. Distribution of RP on scintigram and not lifting of the curve over the area of a small bowel indicates the obstruction of bile duct.

Equipment for detecting of the isotopes uptake and for recording their images includes the gamma camera and the tomographic scanner. Any nuclear medicine research is carried out by radio-electronic devices specially intended for these purposes.

In the majority of devices for nuclear medicine gamma cameras are used which include scintillation counter.

Every such scintillation counter apparatus has three basic elements: detector, photoelectronic multiplier and collimator. Collimator is a device that narrows a beam of gamma-photons. In detector (scintillator) at full or partial absorption of energy of gamma-photons falling on it there are light flashes (scintillation) of very low intensity. Detector is usually a large crystal of sodium iodide containing thallium iodide as activator. To register such flashes, the special device – the photoelectronic multiplier is necessary. In the photomultiplier light energy of flashes turns into a stream of electrons which amplifies like avalanche (fig. 3.18).

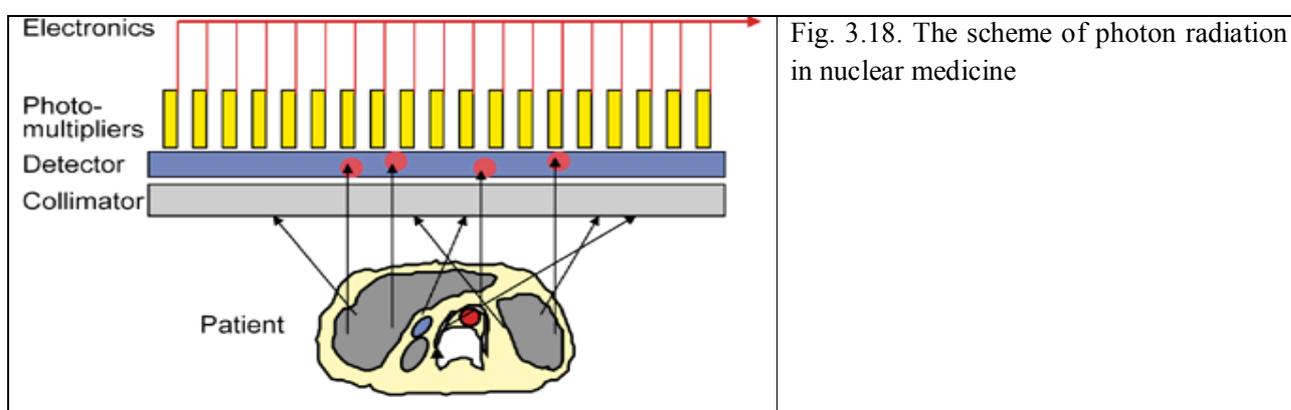


Fig. 3.18. The scheme of photon radiation in nuclear medicine

There are basically five mechanisms of isotope concentration within the body:

1. Blood pool or compartmental localization (e.g., cardiac scan);
2. Physiologic incorporation (e.g., thyroid scan, bone scan);
3. Capillary blockage (e.g., lung scan);
4. Phagocytosis (e.g., liver scan);
5. Cell sequestration (e.g., spleen scan)

Conventional nuclear scans utilize isotopes that produce gamma radiation. Positron emission tomography (PET) scanning uses cyclotron-produced isotopes of extremely short half-life that emit positrons. PET is a nuclear medicine imaging technique that produces a three-dimensional image or picture of functional processes in the body. The system detects pairs of gamma rays emitted indirectly by a positron-emitting radionuclide (tracer), which is introduced into the body on a biologically active molecule. Three-dimensional images of tracer concentration within the body are then constructed by computer analysis. In modern scanners, three dimensional imaging is often accomplished with the aid of a CT X-ray scan performed on the patient during the same session, in the same machine. To conduct the scan, a short-lived radioactive

tracer isotope is injected into the living subject (usually into blood circulation). The tracer is chemically incorporated into a biologically active molecule. There is a waiting period while the active molecule becomes concentrated in tissues of interest; then the subject is placed in the imaging scanner. The molecule most commonly used for this purpose is fluorodeoxyglucose (FDG), a sugar, for which the waiting period is typically an hour. During the scan a record of tissue concentration is made as the tracer decays.

As the radioisotope undergoes positron emission decay (also known as positive beta decay), it emits a positron, an antiparticle of the electron with opposite charge (3.19). Positron emission radionuclides receive by cyclotron (fig. 3.20). The emitted positron travels in tissue for a short distance (typically less than 1 mm, but dependent on the isotope, during which time it loses kinetic energy, until it decelerates to a point where it can interact with an electron. The encounter annihilates both electron and positron, producing a pair of annihilation (gamma) photons moving in approximately opposite directions.

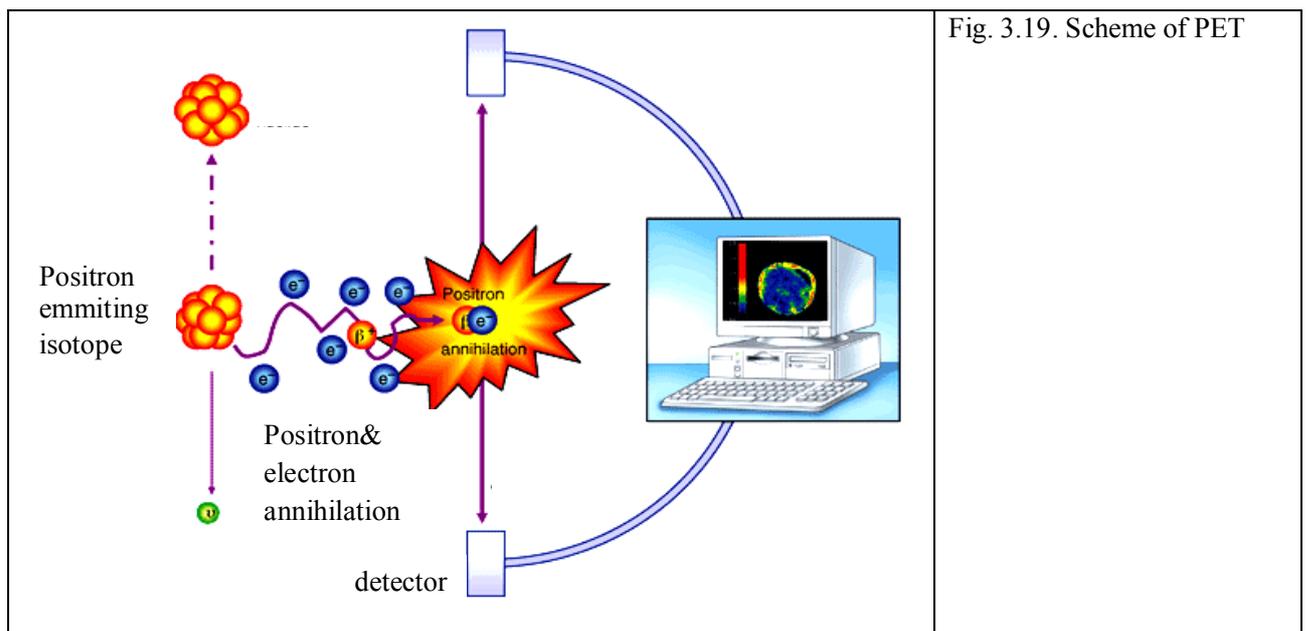


Fig. 3.19. Scheme of PET



Fig 3.20. Cyclotron for production of radionuclides radiating positrons.

Positron emission tomography scanning is used to evaluate physiologic function of organs such as brain or tumors on a dynamic basis. Areas of hyperfixation of radiopharmaceutical show the high level of metabolic activity (fig. 3.21).

If the biologically active molecule chosen for PET is FDG, an analogue of glucose, the concentrations of tracer imaged then give tissue metabolic activity, in terms of regional glucose uptake. Although use of this tracer results in the most common type of PET scan, other tracer molecules are used in PET to image the tissue concentration of many other types of molecules of interest.

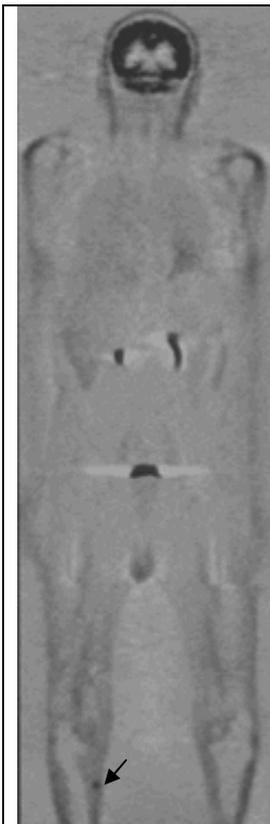


Fig. 3.21. PET imaging.

Coronal whole-body FDG-PET (fluorodeoxyglucose) scan of a patient showing normal FDG accumulation in the brain and the renal excretory system as well as a pathological focal accumulation to the right tibia due to metastasis of malignant melanoma (arrow).

3.4. Diagnostic ultrasound

Obtaining of ultrasonic images of internal organs (structures) of biological objects is based on application of sound field formed in elastic environments (liquid, solid). To investigate biological objects longitudinal acoustic waves of ultrasonic range of frequencies (1-15 MHz) are used. As they distribute, directions of environmental particles fluctuations and wave motion coincide (fig. 3.22). Ultrasound is a nonionizing form of energy. Echoes or reflections of the ultrasound beam from interfaces between tissues with different acoustic properties yield information on the size, shape, and internal structure of organs and masses. However, ultrasound waves are greatly reflected by air-soft tissue and bone-soft tissue interfaces, thus limiting its use in the chest and musculoskeletal system.

Distribution and ultrasound reflexion are two main principles on which operation of all diagnostic ultrasonic equipment is based.

The basis for generation and registration of ultrasonic oscillations is the direct and inverse piezoelectric effect. For obtaining ultrasonic oscillations the inverse piezoelectric effect is used. Its essence lies in the fact that crystal starts to contract and stretch during the formation of electric charges on the crystal face. Oscillations occur,

and their frequency depends on frequency of change of potential sign on crystal faces. One of the main advantages of piezoelectric converters is that the source of ultrasound can serve as its receiver as well. In this case direct piezoelectric effect takes place, when opposite electric potentials are formed on the faces of piezocrystal during its deformation by perceived ultrasound. These opposite electric potentials can be registered. To obtain ultrasonic oscillations, the crystal zirconium titanate is used more commonly.



Three display modes are commonly used (3.23). In amplitude mode (A-mode), information is displayed on a television screen as vertical spikes. The height or amplitude of a spike is related to the size of the echo; the distance from the initial or transducer spike is related to the depth of the reflecting interface from the transducer. Amplitude mode is now used very infrequently for echoencephalography to detect any shift of midline brain structures.

Motion mode (M-mode) is used in echocardiography to study the dynamic changes of the cardiac structures. Essentially the base line is moved at a constant rate on the television screen. The cardiac structures form patterns in the M-mode relating to their motion.

An important advantage of ultrasound is the absence of ionizing radiation and the relatively lower cost of the equipment. However, a great deal of technical skill is required to perform a study. Because ultrasound is unable to cross a tissue-gas or tissue-bone boundary, it is not useful for evaluating the lung or the skeleton.

Furthermore, bony and gas-containing structures can obscure other tissues lying deeper to them.

In brightness mode (B-mode), information is displayed as dots, the brightness of which corresponds to the strength of the corresponding echo. The location of the dot is proportional to the distance of the reflecting interfaces from the transducer. Since this constitutes only a single line on the television screen (corresponding to the line of sight of the transducer), one can build up a cross-sectional image or B-scan by a composite of many such lines obtained during a scan. The images can then be displayed over a wide range of gray scale or shading (Fig. 3.24 and 3.25). In particular, the difference in acoustic properties of various tissues is seen as a difference in the gray scale display of these tissues. Brightness mode and real-time ultrasound techniques are used extensively to evaluate the abdominal viscera, the fetus, and the heart.

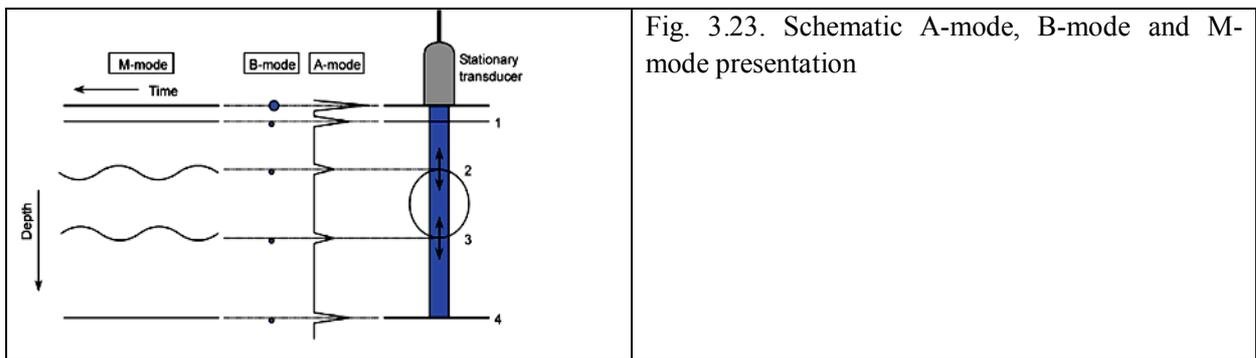


Fig. 3.23. Schematic A-mode, B-mode and M-mode presentation

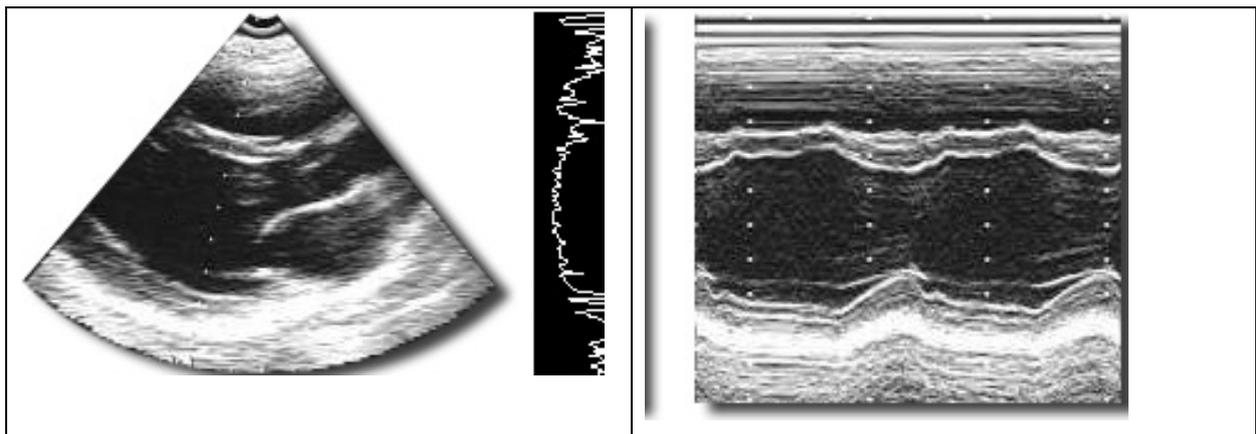


Fig. 3.24. The scheme of one- and two-dimensional modes illustrated by research contractile function of basal portion of the left ventricle. From the left to the right: two-dimensional ultrasonic B-scanning (the arrow shows the direction of ultrasound beam for one-dimensional researches); A-mode in the form of the echogenicity vertical graph of intracardiac structures; M-mode enables to estimate character of movement of cardiac walls in time (throughout all cardiac cycle).

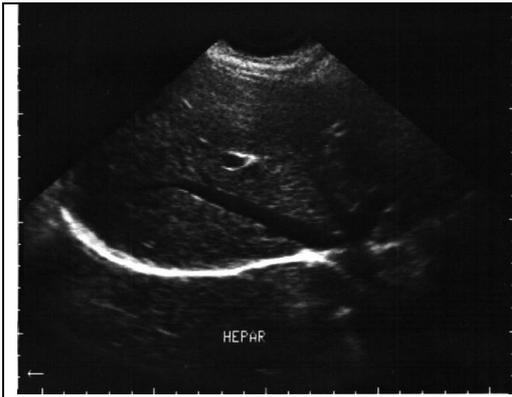


Fig. 3.25. B-mode.
Normal liver sonography. Hyperechoic frames of white color. Hypoechoic frames have black color.

Three-dimensional (3D) mode implies synthesising of a three-dimensional image obtained by electronic or mechanical scanning in two and more planes (fig. 3.26).



Fig. 3.26. Three-dimensional image of a fetus.

Doppler mode. The velocity of blood flow towards or away from an ultrasound probe can be derived from the reflected ultrasound wave using the well known Doppler principle. The effect has found widespread use in fetal monitoring, cardiology and vascular studies. Duplex scanners combine both pulse echo ultrasound and Doppler shift facilities.

Continuous wave Doppler uses two transducer crystals mounted by side, one transmitting and the other receiving ultrasound waves. The method is the best for measuring high velocity flow and for recording peak velocities.

Pulsed-Wave Doppler uses a single transducer to emit short bursts of ultrasound which are received back by the same transducer and recorder in the interval between emission pulses (fig. 3.27). This method permits precise focusing on small sample volumes but is less accurate than Continuous Wave Doppler for peak and high velocity flow.

Colour flow imaging uses pulsed-wave ultrasound but allows assessment across the whole field of two-dimensional image. The results can be coded in colour

permitting immediate visual recognition of flow towards the transducer or away from it.

The power mode allows to register structures with low velocity but without differentiation of their speed, direction and laminarity of a stream.

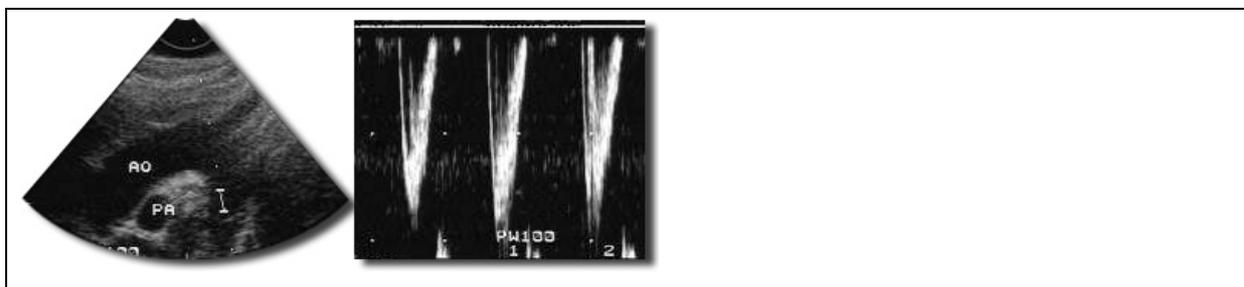


Fig. 3.27. At the left - the two-dimensional image of heart with a label of control volume (in the form of a sign =), established at level of descending department of an aorta (AO). On the right - the schedule a blood-groove through aorta, displaying a direction (from the transducer), speed (amplitude size) and flow disturbances.

When interpreting sonograms echoic indicator is important. Dense structures (e.g. stones) fully reflect ultrasonic waves, therefore they are hyperechogenic. The liquid is homogeneous and it passes freely through ultrasonic waves, therefore it is hypoechogenic. Thus, white sites on sonograms are hyperechogenic, dark sites are hypoechogenic, what is connected with echoic intensity of ultrasound (fig. 3.28).



Fig. 3.28. Sonogram of gallbladder. The stone on the sonogram looks as hyperechogenic formation with an ultrasonic shade behind it (ultrasonic track).
Calculous cholecystitis.

The normal liver serves as a test organ with average echogenicity.

Ultrasonic methods enabled to solve issues of diagnostics of numerous diseases of cardiovascular, digestive, urinogenital systems more precisely. By means of these methods valuable data in obstetrics and gynecology, oncology, neurology and neurosurgery, ophthalmology can be obtained.

Negative effects of ultrasound. One of the main advantages of ultrasound is keeping tissues safe with powers of ultrasound energy used in diagnostics; thus, there are no contraindications for its application. This is important especially for children and pregnant women. However ultrasound should not be considered as an absolutely safe method. Ultrasound influence does not cause ionisation in tissues, but under certain conditions can damage them. Cells with fast fission are the most sensitive to thermal action of ultrasound. Therefore there are certain restrictions for Doppler research for women during I and III trimesters of pregnancy (this method of ultrasound researches has more energy impact on tissues). It is recommended to abstain also from US of a fetus without medical indications.

3.5. Magnetic resonance imaging

Magnetic resonance imaging (MRI) has the major value in modern radiology was got by a. MRI gives the valuable diagnostic information on the physical and chemical parametres, allowing to judge the nature and a morphological structure of investigated organs and tissues. Besides the image can be received in any plane. The basic components of the MR-tomograph are the power magnet, a radio transmitter, the reception radio-frequency coil and the computer (3.29).



Fig. 3.29. MRI machine.

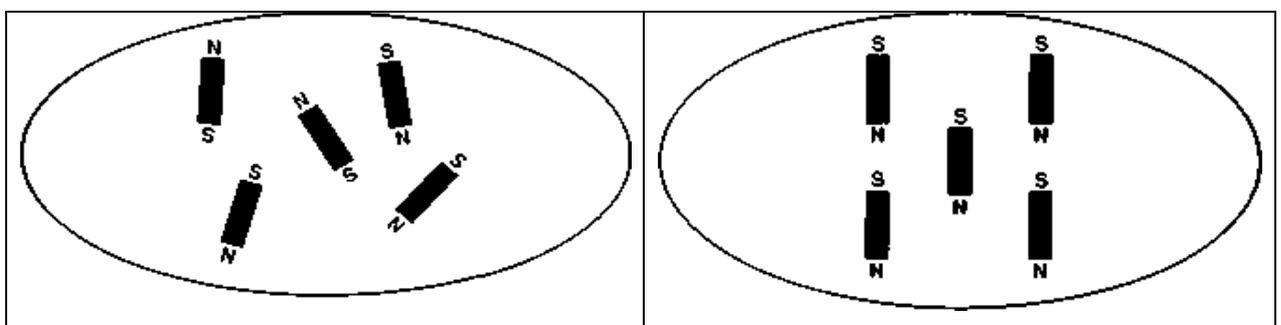
The majority of magnets have a magnetic field which is parallel to a long axis of a person's body. Force of a magnetic field is measured in tesla (T). For clinical MRI fields with force 0,02-3 T are used. When the patient is put in the strong magnetic field, all small proton body magnets (a hydrogen nucleus) turn towards an

external field (like the compass arrow which is guided by a magnetic field of the Earth). Besides, magnetic axes of each proton start to rotate round a direction of an external magnetic field. When passing through a patient's body of the radio-waves with the frequency equal to the protons rotation frequency (Larmor frequency), a magnetic field of radio-waves forces the magnetic moments of all protons to rotate clockwise. This phenomenon is called magnetic resonance. Resonance is understood as synchronous vibrations. To change orientation of a magnetic vector of protons, magnetic fields of protons and radio-waves should resonate, i.e. they should have identical frequency. In tissues of the patient the total magnetic moment is created when tissues are magnetized, and their magnetism is oriented precisely parallel to an external magnetic field (fig. 3.30).

The MRI reflects the strength or intensity of the MR radiofrequency signal received from the sample. Signal intensity depends on several factors such as hydrogen density and two magnetic relaxation times (T1 and T2). The greater the hydrogen density, the more intense (bright) the MR signal will be. Tissues that contain very little hydrogen such as cortical bone, flowing blood, and air-filled lung, generate little or no MR signal and appear black on the images produced. Tissues high in hydrogen, such as fat, have high-signal intensity and appear white.

T1 and T2 measurements reflect quantitative alterations in MR signal strength due to interactions of the nuclei being studied and their surrounding chemical and physical characteristic. T1 is the rate at which nuclei align themselves with the external magnetic field after radiofrequency stimulation. T2 is the rate at which the radiofrequency signal emitted by the nuclei decreases after radiofrequency perturbation (fig. 3.31).

At present magnetic resonance is used mainly for studying intracranial and intraspinal pathology, and for evaluating abnormalities of the musculoskeletal system and the heart. Less commonly, it is used to evaluate abdominal visceral problems.



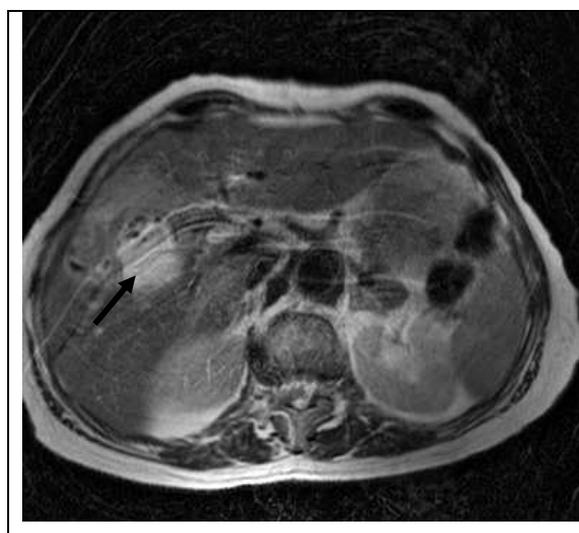
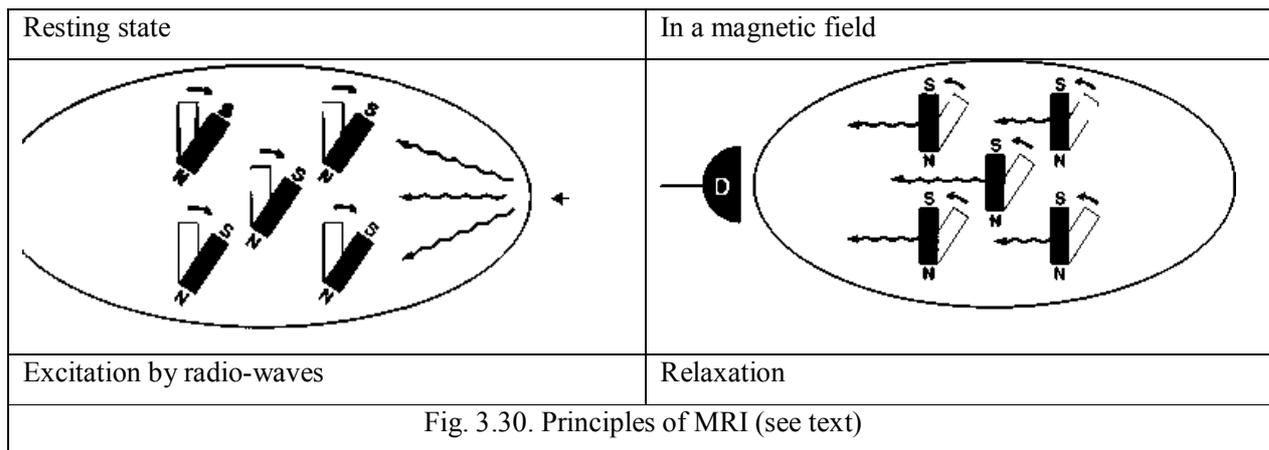


Fig. 3.31. The T2-weighted image.
Liver abscess (arrow).

Agents to enhance MRI. Despite the wide variety of pulse sequences available for MR imaging difficulties still exist for differentiation between neoplasm and chronic cerebral infarction, tumor and perifocal cerebral edema, or recurrent herniated intervertebral disc and surgical scar. For these reasons, a number of paramagnetic contrast agents have been developed for intravenous use during MR imaging. To date, gadolinium-diethylenetriaminepentaacetic acid (Gd-DTPA) is most commonly used. Gadolinium was chosen because of its strong effect on the relaxation time in the scanning sequence. Chelation with DTPA has reduced the inherent toxicity of the free Gd ion. In diagnostic doses, Gd-DTPA increases the signal in vascular structures, similar to the effect of conventional water-soluble contrast media.

Disadvantages of MRI:

1. Poor calcification imaging.

2. Long time of imaging; artifacts from respiratory and other movements limit the application of MRI in diagnostics of chest and abdominal diseases.

Negative effects of MRI. MRI systems do not use ionizing radiation and have no radiation harm. For the overwhelming majority of patients the method is not dangerous.

MPT is contraindicated for:

1. Patients with pacemakers or with intraorbital, intracranial, intraspinal and other ferromagnetic foreign bodies (absolute contra-indication).
2. Intensive care patients because of influence of magnetic fields of the MRI on life-support systems.
3. Claustrophobic patients (about 1%), though they can be sedated
4. Women during their first trimester of pregnancy.

CHAPTER 4. RADIATION INJURIES IN RADIOLOGY AND RADIOTHERAPY

Nowadays radiology and radiation oncology makes the greatest contribution to a dose received by a person from anthropogenic sources of radiation. Borders of radiological examinations are from 0,04 up to 1,0 mSv at the lowest and highest levels of health services. In radiotherapy the largest local total doses are 60-70 Gy.

4.1. Classification of radiation injuries

According to modern data the basic determined effects of the total irradiation are represented as follows (tab. 4.1):

Table 4.1. Biological effects of acute radiation exposures

Radiation dose	Effect
0,1 Gy to bone marrow	Risk of leukemia may be elevated.
0,1 Gy whole body	Elevated number of chromosome aberration: no detectable injury or symptoms.
1 Gy whole body	Mild radiation sickness – nausea, vomiting, fatigue are possible
4 Gy whole body	Likely to result in death for 50% of exposed and untreated population.
10 Gy to skin	Erythema and blistering

40 Gy or more, whole body	Death within 48 hours from shock and vascular damage
60 Gy small volume	Used to treat cancer over 6 weeks.

On the whole, laws of a radiation injury in an organism are defined by two factors:

1. Radiosensitivity of tissues, organs and systems essential for a survival of an organism.
2. Amount of the absorbed dose of radiation and its distribution in space and time.

These factors individually and combined determine the primary type of beam effects (local or the total), specificity and time of display (it is soon after an irradiation or in the remote terms) and their importance for an organism.

The best understanding of the basic displays of a radiation injury can be achieved by their comparison to the absorbed dose in “critical organs”. Critical organs are vital organs or systems, are organs which are first affected by a certain radiation dose what causes destruction of an organism in the certain terms after irradiation. It is very important to distinguish deterministic and stochastic radiation effects.

Deterministic effect is clinically detected harmful biological effect caused by ionizing radiation concerning which there is a threshold. If the effect is lower than the threshold the effect is absent, if it is higher the effect severity depends on a doze.

Stochastic effect is harmful biological effect caused by ionizing radiation. This effect hasn't got a threshold dose. The severity of irradiation effects doesn't depend on a dose and it is determined by the character of the inducted radiation pathology.

For radiation protection, according to recommendations of International Commission on Radiological Protection (ICRP) it has been made an assumption, that stochastic effects have nonthreshold linear dependence.

Early radiation lesions are lesions occurring within first three months after irradiation. Late radiation lesions are lesions occurring later than three months after radiation exposure.

In radiobiological and clinical practice radiation reactions and radiation damages are distinguished.

Radiation reactions are such changes in tissues, which pass within 2-3 weeks after irradiation without special treatment. For example it is skin erythema.

Radiation lesions are organic and functional changes in organs and tissues which demand special treatment.

4.2. Medical irradiation at radiotherapy

In radiotherapy of malignant tumours the absorbed doses of ionizing radiation are defined by clinical indications according to principles of radiation oncology and directed to achievement of the maximal selectivity of tumour lesions. As the used doses are large, as opposed to radiodiagnostics, beam influence on patients can be accompanied by non-stochastic (deterministic) effects from the side of healthy tissues (see by tab. 2).

Table 2. Estimations of approximate threshold dozes for clinically harmful non-stochastic effects in various tissues, based on reactions of patients on conventional fractionation x-ray or gamma irradiation

Organs	Damages in 5 years	A dose causing effect at 1 - 5 % of patients, Gy	The area of a field of an irradiation
Skin	ulceration, fibrosis	55	100 sm ²
Mucous a mouth	the same	60	50 sm ²
Stomach	ulceration	45	100 sm ²
Thin bowel	ulceration, narrowing of the channel	45	100 sm ²
Large bowel	the same	45	100 sm ²
Liver	hepatic insufficiency	35	Entirely
Kidneys	sclerosis	23	Entirely
Bladder	ulceration, contraction	60	Entirely
Testicle	constant sterility	5-10	Entirely
Ovary	The same	2 - 3	Entirely
Uterus	necrosis, perforation	100	Entirely
Capillaries	telangiectasia, a sclerosis	50 - 60	-
Heart	pericarditis, pancarditis	40	Entirely
Bones at adults	necrosis, crises	60	10 sm ²
Cartilage at adults	necrosis	60	Entirely

CNS (brain)	necrosis	50	Entirely
Spinal cord	necrosis	50	5 sm ²
Eye	panophthalmitis, a haemorrhage	55	Entirely
Crystalline lens	a cataract	5	Entirely
Thyroid gland	hypothyroidism	45	-
Muscles at adults	An atrophy	100	Entirely
Bone marrow	hypoplasia	2	Entirely
Bone marrow	hypoplasia	20	Locally
Lymph nodes	an atrophy	35 - 40	Locally
Lymphatic vessels	a sclerosis	50	Locally
Foetus	destruction	2	Entirely

4.3. Reactions and damages at radiotherapy

As it was specified in previous chapters, main principle of radiotherapy is to provide optimum influence of radiation on a tumour under condition of maximal possible sparing of surrounding organs and tissues. However it is hardly possible to avoid completely irradiation of healthy tissues, especially if tumours are deeply located.

It should be mentioned, that the deviation of a dose in 5 % is considered to be critical, both for treatment of a tumour, and for influence on healthy tissues. Because of a small distinction interval between radio-sensitivity of a tumour and healthy tissues surrounding it, and despite development and perfection of radio-therapeutic techniques, radiation lesions of skin and other tissues may occur. It is necessary to admit, that a part of people (from 5 up to 10 %) are highly sensitive to ionizing radiation action, but it is impossible to diagnose individual radio-sensitivity beforehand. Necessity of studying of late radiation lesions is caused not only by frequency of their development, but by long torpid clinical manifest.

Depending on manifestation of radiation response it can be local and the total.

Total radiation response in radiotherapy.

The total radiation response is a reaction of the whole organism to the influence of ionizing radiation, which declares itself by increased temperature, disorders of gastrointestinal tract function (dysorexia, nausea, vomiting and diarrhea), cardiovascular system (tachycardia, hypotonia) and changes in nervous and haematogenic systems.

Total radiation response is realized as a result of direct and indirect local action of ionizing radiation. As a result of direct lesion in the area of radiation exposure there is a suppression of hematosis if it enters a zone of bone marrow irradiation and effect on peripheral blood cells (lymphocytes). Moreover, there is also a mediated damage to the organism realized as a result of radiotoxins influence: lipidic peroxides, quinone derivatives, protein radiotoxins (owing to disintegration of tumour cells and healthy tissues), histamine and choline. These connections cause intoxication and can cause hematosis suppression, that expresses in granulocytopenia, lymphopenia with the subsequent development of thrombocytopenia and, less often, anemia.

Total radiation response degree extensively depends on radiation dose and its fractionation regime as well as on individual radio-sensitivity of a patient. There is a certain dependence on body area and volume of the tissues, exposed to irradiation. The most sensitive organs with regard to development of the total radiation response are the top part of the stomach, the head and the thorax.

According to classification of the World Health Organization experts the following total radiation responses are distinguished:

1. Mild radiation response: loss of appetite, nausea, unitary vomiting;
2. Moderately severe response: constant nausea, vomiting during the first and second half of treatment, general weakness;
3. Severe response: repeated vomiting during all the course of radiotherapy (both in the day of irradiation, and in days when irradiation was not performed).

Thus, leading clinical signs are nausea and vomiting.

Severe radiation response, leukopenia (is lower $3 \times 10^9/l$) demand a break in treatment. Total radiation response is convertible. All disturbed processes in organs and systems are gradually restored and get back to normal in 3-8 months.

Radioprotectors can be applied to prevent total radiation response: mexamin hydrochloride 0,05 30 minutes prior to a session of radiotherapy; cystamine dihydrochloride 0,2-0,8g daily or every other day 1 hour prior to irradiation. In severe response at subtotal or total irradiation hemosorption is applied. Colony-stimulating factors of granulocyte, in particular - leukomax (recombinant human granulocyte-macrophage colony-stimulating the factor) - 3 mkg / kg up to 10 mkg / kg of weight per day are very effective. The maximal duration of treatment takes 10 days.

Such antiemetic drugs as aminazine (25 mg 1-3 times a day) and cerucalium (10 mg before a meal by 1-2 tablets 2-3 times a day) are indicated.

Medicines raising arterial pressure (in hypotonia) should be prescribed to the patients, suffering from cardiovascular diseases.

Complex use of the mentioned measures allows to carry out a full course of radiotherapy without radiation response manifestation. In cases, when, despite preventive measures, there are symptoms of total radiation response, it is necessary to make a break in irradiation, however it is necessary to remember, that infringement of irradiation rhythm, especially in the first half of the course, has an adverse effect on results of treatment. Therefore the induced break in the absorbed dose of 20-30 Gy should not exceed 3 days. In a dose of 40-50 Gy, depending on character of disease, such breaks in radiotherapy can be increased till 10-14 days.

Local radiation lesions in radiotherapy. Local radiation lesions may be early and remote. Recovery of sublethally irradiated cells occurs within 100 days (within 3 months). If radiation lesions occur during this term they are called early radiation lesions. All disorders developed later, are late (remote) radiation lesions.

Local radiation response.

Reactions of a skin and subcutaneous cellulose are the most often since these tissues are first exposed to radiation influence at external irradiation. Most frequently skin reactions are observed when using opposite fields.

Radio-sensitivity of skin depends on several factors. So, there are individual fluctuations of radio-sensitivity of skin; the skin of women is less radiosensitive, than the skin of men. Skin possesses regional radio-sensitivity which decreases in the following order: neck, breast, belly, hips, back, and face. Skin is most sensitive in axillary and inguinal areas, in internal surface of hips and in neck area. In Basedow's disease, nephritis and diabetes the radio-sensitivity of skin rises. Inflamed and hyperemic skin becomes more radiosensitive.

Following skin radiation responses are distinguished: erythema and radiodermatitis (dry and wet). Erythema is an expressed skin hyperemia in a zone of irradiation; it is accompanied by puffiness and moderate itch. In a basis of erythema development there is the expansion of skin capillaries.

In other equal conditions erythema develops after a unitary irradiation at a lowvoltage x-ray irradiation dose of 4 Gy and 7,5-8 Gy gamma ray radiation. At conventional fractionation of gamma rays radiation erythema develops after a dose of 30-35 Gy. 2-3 weeks after the end of irradiation the mentioned phenomena usually disappear or, according to a field of irradiation, there is a slight pigmentation with the subsequent desquamation, lasting for some months.

Dry radiodermatitis is a change of a skin in a zone of irradiation. Skin is dry, hyperemia accompanied by pigmentation, puffiness and itch. Dry radiodermatitis

usually develops after a unitary irradiation in 8-12 Gy doze of gamma-rays radiation or 40-50 Gy fractional radiation.

In these cases recovery of irradiated skin is not always complete as uneven depigmentation or telangiectasis (resistant expansion of small hypodermic blood vessels) can develop.

Moist weeping radiodermatitis is characterized by formation of blisters with serous or serous-purulent contents accompanied by hyperemia and puffiness of the irradiated skin. Moist radiodermatitis usually develops after high total doses of irradiation (more than 50 Gy) or 12-16 Gy unitary (one-time) gamma-rays of radiation.

Epithelization is slow and skin after it remains dry, pigmented and atrophic (fig. 4.1, 4.2).



Fig. 4.1. Moist radiodermatitis. Large bulla on palmar surface of the hand.



Fig. 4.2. Moist radiodermatitis. The bulla has completely broken, defeat has extended on index and average fingers.

Skin radiation reactions are always accompanied by loss of hair in a zone of irradiation.

Depending on severity of radiation reactions epilation can be constant and temporal, when hair grow, but it is, as a rule, defective (rare, dry and gray). The threshold absorbed dose of irradiation causing epilation, is close to 2,5-3 Gy on the head.

At this and higher dose, approximately up to 6 Gy, the expressed epilation starts on the 14-17th day of illness. At the extremely high degree of lesion epilation occurs on the 8-9th day (fig. 4.3).

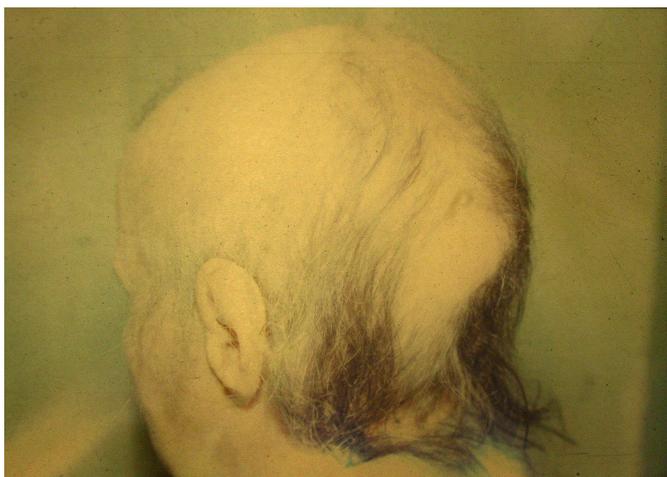


Fig. 4.3. Epilation. Loss of hair 3 weeks after external radiotherapy on the brain in total dose 30 Gy (a single dose 3 Gy) concerning cancer metastasises in a brain.

Radiation Histopathology of skin:

- Erythema is arteriolar constriction with capillary dilation and edema, with extravasation of leukocytes and erythrocytes.
- Dry desquamation is reflection of response of the germinative epidermal layer, diminished mitotic activity; swollen cells of the basal and parabasal layers; thin epidermis; desquamation of large macroscopic flakes of skin.
- Wet desquamation is an intracellular edema; vesicles coalesce to form bullae exterior to the basal layer, epidermis may slough, exposing the dermal surface, coated by fibrin.

Acute radiation dermatitis:

- Cells of the basal layer are decreased in number and lose cohesion and intracellular binding.
- Intracellular and extracellular vacuolation is present.
- Arrest of mitosis in proliferative layer.
- Shortened life – span of progenitor cells.
- Thickened dermal collagen and elastic fibers.

Radiation reactions of mucous membranes (mucositis, radiation epitheliitis) develop when hollow organs are irradiated. They can simultaneously be observed

with skin radiation reaction or separately. But as mucous skin reactions possess high radio-sensitivity its radiation reactions can arise in smaller doses, than reactions of skin.

Following stages of radiation epitheliitis are distinguished:

- The stage I of epitheliitis is characterized by hyperemia and a slight mucous membrane edema. Then cornification of epithelium occurs and mucous becomes whitish, grown turbid and dry;
- The stage II is characterized by rejection of the cornified epithelium and formation of single erosions with necrotic incrustation (a stage of multifocal membranous epitheliitis);
- The stage III is characterized by extensive rejection of epithelium and formation of solid erosive surface (a stage of confluent membranous epithelitis).

Conjunctiva is the most radiosensitive mucous membrane. Between 17th and 21st days after a dose of irradiation in 25-30 Gy conjunctiva becomes red in 2-3 days, then erosions and dyphthteria-like a strike incrustation appear owing to fibrin transudation. Usually, if overdoses were absent, all phenomena pass in 2-3 weeks after treatment. The mucous membrane of the mouth during irradiation becomes edematous, hyperemic and painful. Dryness in a mouth connected with suppression of salivary glands functions is often observed, as well as infringement of taste.

Irradiation of the throat and pharinx cause changes in the mucous membrane and are clinically expressed in fugacious phenomena: voice hoarseness, pains and difficulty at swallowing. The beam laryngitis arises usually in a dose of 40-45 Gy.

Reaction of bronchial tubes is expressed in dry cough, dyspnea, chest pains, and sometimes a moderate rise in body temperature. Radiations pneumonia develops quite often too.

Reaction of esophagus mucous is characterized by dysphagy (feeling of burning and difficulty at passage of food), retrosternal pains, pains in interscapular space, sialorrhea. Esophagitis can arise in a dose of 30-40 Gy.

Reaction in the urinary bladder mucous membrane is expressed by painful urination, pains in the bottom of the abdomen. It arises usually in a dose of 35-40 Gy.

The mucous of the uterus possesses rather high resistency. Epitheliitis in this organ can develop in a dose of above 60 Gy.

To prevent local radiation reactions of skin it is usually covered with vegetable and animal oils, indifferent creams. In erythema vitaminized cod-liver oil sea buckthorn oil, 0,5% prednisolone ointment are used. In development of dry radiodermatitis 0,5 % prednisolone ointment is used. Ointment is applied to the

irradiated skin twice a day (in the morning after night sleep and in the afternoon after lunch sleep; it is needn't to apply ointment before going to bed as it will be removed during the sleep). Treatment of wet radiodermatitis is performed more often in the open way without a bandage. Vitaminous preparations are widely used: pantenol-spray, "Olazolium", 5 % - 10 % dimexidum solution in radioepitheliitis.

For prevention and treatment of radioepitheliites it is necessary to avoid mechanical and thermal influence, 0,25 % - 1 % novocaine solution, oil irrigation (olive, sunflower, peach oil) should be applied.

To prevent radiation pneumonitis and to alleviate its course glucocorticosteroids are applied.

Treatment of radiation cystitises and rectitis is basically performed by washing the bladder and the rectum with antiseptic solutions (Furacillin 1:5000), the rectum is daily washed out with a warm chamomile tea solution. Before bedtime Microclysters with vaseline oil, rosehip oil and a 5 %dimexidum solution are indicated.

Radiation damages.

In early radiation damages, i.e. in such radiation injuries when independent recovery is impossible, more radiosensitive and well recycling structures suffer.

Sharp necrosis induced by radiation has a severe course. In 7-10 days erythema receives persistent character; it is accompanied by severe pains, deterioration of the general condition and rise in temperature. Peripheral lymph nodes increase. In the first days after irradiation bubbles with a clear liquid appear. After bubbles opening and epidermis rejection necrotic tissues becomes evident; it is covered with yellowish incrustation. After rejection of necrotized tissues the deep ulcer is found out. The process is accompanied by severe pains, however in some cases early radiation necroses can develop without the expressed pains or edemas. Sharp radiation necrosis is observed at large doses of fractionated irradiation (about 100 Gy and more) at single dozes more than 20 Gy-50 Gy.

Infringements of more radioresistant structures demanding more time for radiation damage realization at same doses of ionizing radiation lies in the basis of late radiation damages. Clinical displays of late radiation damage are consequences of gradual accumulation of changes in the small blood vessels and lymphatic vessels causing infringements of microcirculation and development of irradiated tissues hypoxia; its consequence is fibrosis and a sclerosis.

Destruction of cellular elements with their replacement with cicatricial tissues and sharp suppression of reparative opportunities of cells also play an essential role.

Late beam damages are:

1. Atrophic processes (fig. 4. 4).
2. Hyperplastic processes.
3. Radiation fibrosis or indurative edema.
4. Radiation ulcers, late necrosis (fig. 4.5)
5. Radiation cancer.



Fig. 4.4. Atrophy of skin with sites of depigmentation and angiectasia (dilation of blood vessels) in the field of the left clavicle 5 years after external radiotherapy concerning breast cancer in total dose of 50 Gy with usual fractions (2 Gy).



Fig. 4.5. Late radiation ulcer on skin 7 years after lowvoltage x-rays radiotherapy squamous cell skin cancer in total dose 75 Gy.

Treatment of radiation damages. Treatment should be complex, combining the common actions with local influence on the damaged skin. The common medical actions are directed on increase of a vitality of an organism and activation of reparative process is reached by high-calorific meals, vitamin complexes, fresh fruit and vegetables.

The daily toilet of an ulcer and its d-bridement with solution of antibiotics is recommended. Later bandages with ointments containing sea-buckthorn oil are

imposed. Sometimes Novocaine blockade of 0,25% solution is applied. When conservative treatment is inefficient at anatomic permissibility there arises a question on early surgical intervention with necrectomy or amputation of the struck segment of extremity not later, than in 2-2,5 months, i.e. in terms when necrosis areas are being outlined. The terms of severe lesions treatment are delayed to 0,5-1 year.

The treatment of late radiolesions should be planned with consideration to clinical form of a lesion. In atrophic dermatitis it is recommended to apply steroid and vitaminized oils. In treatment of hypertrophic processes and fibrosis absorbing preparations, such as dimexidium, lidasa and glucocorticoid are applied. Purposeful medicinal electrophoresis of dimexidium, heparinum and proteolytic enzymes quite often gives good therapeutic effect. This technique yields good results in treatment of late radiation ulcers as well as necrosis. However the basic method of treatment of such lesions is radical excision of the damaged tissues with the subsequent skin-plastic defect replacement.

Radiating protection of patients in radiotherapy.

In radiotherapy of malignant tumours the absorbed doses of ionizing radiations are defined according to clinical indications in compliance with principles of radiation oncology and are directed to the achievement of the maximal selectivity of tumours defeat. As the used doses are larger than those in radiodiagnostics, the radiation influence on patients is accompanied by the determined effects on the part of healthy tissues. Patients, suffering from such diseases, cannot cause the essential contribution to genetically significant dose due to a disease character and a patient's age. Taking in account the latent period the risk of a new tumour development after therapeutic irradiation is practically insignificant.

At the same time, in radiotherapy the determined lesions have special value taking into account, that a 5 % deviation in a used dose is considered to be critical both for treatment of a tumour and for influence on normal tissues.

Thus the principle of substantiation and optimization is used according to ICRP. When carrying out radiotherapy all possible measures of radiation complications prevention in the patient should be taken.

The most important for patients' protection in radiotherapy is the exact leading of correctly appointed dose of radiation to a zone of tumour lesion with minimally possible irradiation of healthy tissues.

In this connection great demands of dosimetric maintenance of radiotherapy are made. Therefore the equipping of radiological departments by radiological simulators, dosimetric and planning systems is provided.

The x-ray computer tomographs allowing with great accuracy to transfer geometrical parameters of irradiated structures in computer systems for radiation therapy planning have great value.

The control of correctness of the beam fields of irradiation is established with the help of special device – a radiological simulator of irradiation which allows to carry out fluoroscopy and radiography with the exact localization of irradiation field and the choice of radiation direction taking in account the target volume.

For performance of complex dosimetric calculations digital copies of x-ray computer tomograms are transferred to the computer system of irradiation planning. To use a computer in irradiation planning, the program of the warranty, including the test program should be prepared to be confident that the computer system of planning of irradiation works with stable accuracy.

Planning of irradiation in radiation therapy with the use of open radionuclide sources is based on the metabolism of a radiopharmaceutical preparation and its physical characteristics. On the basis of this information, knowing weights of organs and tissues calculations of radiation doses both in target volume and organs at risk are performed.

In external irradiation the position of the patient should be reproducible. The patient should be in convenient position; if necessary immobilization means are used. These means are applied to reproduce the position of the patient at each irradiation session; they have special value when it is difficult for a patient to keep the necessary position for irradiation.

It is necessary to calculate duration of irradiation and check it up beforehand and independently.

For protection of normal tissues absorbing materials are frequently placed in a radiation beam: multi-leaf collimator, blocks, wedge filters, the trellised diaphragms. JGRT technique is also used.

The control of a radiation beam characteristics and direct measurements over the patient are carried out with the help of corresponding dosimeters. In the external irradiation dose measurements should give radiation doses in certain points under certain conditions with a margin error $\pm 3\%$. Measurements of deep doses, factors of easing wedge filters and prefixes for blocks should be carried out with a margin error 0,5-2 %. Activity of the used radionuclide it is necessary can have a margin error $\pm 5\%$.

There are programs of quality assurance of the equipment for radiotherapy, including reception tests and periodic operational tests for check of an invariance of entry conditions.

Radiating protection of personnel during radiotherapy. Beam treatment methods depending on a degree of radiating danger can be arranged in the following order: intracavitary therapy with the help of traditional methods of introduction of radioactive preparations, therapy with the help of hose devices and remote therapy.

4.4. Medical irradiation in radiology

The most widespread kind of radiation used in diagnostic purposes is X-ray. The data of research results show, that over 50 % of the population receives doses of irradiation during X-ray examination.

Of all methods of beam diagnostics only X-ray and radionuclide « in vivo » researches are connected to the influence of ionizing radiation on a patient's organism.

Radionuclide diagnostics gives considerably less contribution to a collective effective dose of population irradiation, than radiological researches (in 10 times and more), that is connected with lower frequency of radionuclide researches application in clinical practice. At the same time, real effective doses on one patient in some kinds of radionuclide researches can exceed doses of irradiation from many kinds of X-ray researches.

Table 4.2. Doses used for radiologic investigations

Type of research	Dose (mSv)
Chest film	0,1-0,2
Fluoroscopy of chest with image-enhanced	3
Fluoroscopy of chest non-image-enhanced ("conventional")	5
Fluoroscopy of stomach or intestine with image-enhanced	10
Fluoroscopy of stomach or intestine with non- image-enhanced ("conventional")	20
Film of leg or arm	0,1
Film of vertebrae	1,6
Pelvic CT	15-25

Chest CT	3
Head CT	0,2-0,4
Nuclear medicine study (average level for one research)	4,5

Thus doses can induce stochastic effects: malignant tumors and hereditary effects.

Risk of malignancies: lifetime probability of radiation induced fatal cancers – 5% per 1000 mSv in nominal population of all ages.

Risk of hereditary effects: probability of hereditary effects for all generations: 1,2% per 1000 mSv. Probability of hereditary effects for two first generations: 0,3% per 1000 mSv. Probability of hereditary effects in the first 1 generation: 0,2% per 1000 mSv.

Radiation effects on the embryo. Effects of radiation in utero are generally referred to as effects on the embryo. They can occur at all stages of embryonic development, from zygote to foetus and may include lethal effects, malformations, mental retardation and cancer induction. The first three may be the possible outcome of deterministic effects during embryonic development, particularly at the period of formation of organs.

Evidence of effects on brain growth and development has emerged after observations of severe mental retardation in some children exposed in utero at Hiroshima and Nagasaki. The effects from high-dose, high-dose-rate exposure in utero, particularly linked to the period between 8 and 15 weeks after conception, seem to indicate a downward shift in the intelligence quotient (IQ) distribution. For low radiation doses, this potential effect on the embryo is undetectable in the newborn.

Studies of in utero exposures have given conflicting evidence of carcinogenesis in the child, from relatively high risk to essentially small undetectable risk. There is no biological reason to assume that the embryo is resistant to carcinogenesis but on the basis of current data such effects cannot be quantified with any certainty.

Risk of effects on an embryo: (for those exposed in utero in the period between 8 and 15 weeks after conception). Downward shift of IQ distribution: dose required to shift from normal IQ to severely mentally retarded: 1000 mSv or more.

Measures on restriction of medical irradiation in radiology. Radiation protection principles. There are four basic radiation protection principles that can be employed to reduce exposure of ionizing radiation. These principles are based on

consideration of *four radiation protection factors* that alter radiation dose, time, distance, shielding, and quantity.

Time is an important factor in radiation protection. This principle states that the shorter the time spent in a radiation field, the less radiation will be accumulated. Depending on the activity present, radioactive material will emit a known amount of radiation per unit time. Obviously, the longer a person remains in a radiation field, the more radiation that person will accumulate.

Distance. The second radiation protection factor is *distance*, and the principle is the farther a person is from a source of radiation, the lower the radiation dose. This principle is known as the inverse square law. By measuring the radiation exposure rate at a given distance from a source of radiation and then doubling the distance from the source, the intensity of the radiation is decreased by a factor of four. For example, a source of radiation that measures 8 mR/hr at 2 feet from a source would measure only 2 mR/hr at 4 feet. Conversely, when the distance from the source of radiation is reduced by half, for example, from 2 feet to 1 foot, the exposure rate increases from 8 mR/hr to 32 mR/hr, a factor of four.

Shielding. The third radiation protection factor is shielding. The principle follows that the denser a material, the greater is its ability to stop the passage of radiation. In most cases, high-density materials such as lead are used as shields against radiation. Portable lead or concrete shields are sometimes used when responding to accidents where contamination levels are very high.

In emergency management of the contaminated patient, shielding is limited to standard surgical clothing with slight modifications. Surgical clothing will protect the individual against contamination, and also will stop the passage of all alpha and some beta radiation. However, it does not stop penetrating gamma radiation. In the hospital emergency department shielding is actually limited to anti-contamination measures, and the principles of time and distance are used to reduce radiation exposure.

Quantity. The fourth radiation protection factor is *quantity*. Because the exposure rate from a given radioactive material is directly related to the amount or quantity of the material present, the principle involves limiting the quantity of radioactive material in the working area to decrease radiation exposure. Any technique that reduces the amount of radiation or radioactive material in the treatment area is very useful.

At work with the closed sources of radiations there is a potential danger of radioactive pollution of integuments, overalls and working surfaces due to infringement of tightness of sources. It is necessary for taking into account at carrying out of a

sanitary - radiation control. Check of tightness of the closed sources is necessary for carrying out on a regular basis by the developed techniques (smear dry and damp materials with the subsequent radiometric in the well counter). Also the regular control over radioactive impurity of hands, overalls, toolkit and working surfaces is necessary. At work with the closed sources of the small sizes there is its danger loss. In such cases it is necessary to have a dosimeter - radiometer with which help it is possible to start searches of the lost source immediately.

At work with the closed sources of special requirements to furnish of rooms do not show. The closed radioactive preparations, not suitable for whatever reasons to further use, are considered as radioactive waste products and when due hereunder surrender on a burial place.

The purpose of protection against radiation is elimination of the determined radiation injuries and decrease in somatic and genetic risk for patients and the personnel.

According to ICRP for maintenance of normal operation of sources of radiation it is necessary to be guided by the following main principles of radiation safety:

1. Non overflow of allowable limits of individual doses of irradiation of the person from all sources of radiation (a principle of normalization);
2. Prohibition of all kinds of activity connected with the use of irradiation sources at which the received benefit for a person and a society does not exceed the risk of possible harm caused by additional irradiation (a principle of a substantiation);
3. Maintenance of individual doses of irradiation and irradiated persons on possible low and achievable level in view of economic and social factors using any source of radiation (a principle of optimization).

Principles of control and restriction of radiation influence in medicine are based on reception necessary and the helpful information or therapeutic effect at minimally possible levels of an irradiation. Thus limits of doses are not established, but principles of a substantiation of purpose of radiological medical procedures and optimization of measures of protection of patients are used.

Radiating safety of patients and the population should be provided at all kinds of a medical irradiation (preventive, diagnostic, medical, research) by achievement of the maximal benefit of radiological procedures and all-round minimization of radiating damage at the unconditional superiority of benefit for irradiated above harm.

The medical irradiation of patients with the aim of reception of the diagnostic information or therapeutic effect is carried out only to destination the doctor and with the consent of the patient. The final decision on carrying out of corresponding procedure is accepted by the doctor – radiologist.

The medical diagnostic irradiation is carried out on medical indications when other methods are impossible, or they are insufficiently informative.

All used methods of radiology and radiotherapy should be authorized by state public health services. In the description of methods it is necessary to reflect optimum modes of performance of procedures and levels of irradiation of the patient at their performance.

Rules of all kinds of radiological diagnosing researches should guarantee the absence of the determined radiation effects.

The irradiation of people with the purpose of reception of the scientific medical information can be carried out under the decision of the republican state public health services, within the limits of the established allowable levels of irradiation at the obligatory written approval surveyed after granting of data about possible consequences of irradiation.

In carrying out of radiotherapy all possible measures for prevention of beam complications in a patient should be taken.

For radiological medical researches and radiotherapy the equipment registered by republican state should be certified.

The medical personnel engaged in radiological diagnostics and therapy is obliged to provide protection of a patient, supporting individual doses on possible low level of irradiation. The dose received by a patient is subjected to registration.

Doses of irradiation of a patient received during radiological researches and procedures should be registered in a personal sheet of the doses account of medical irradiation, being the obligatory appendix to his out-patient card.

The medical personnel has no right to increase irradiation of a patient directly or indirectly to reduce own professional irradiation.

Introducing radiopharmaceutical preparations with therapeutic purposes to a patient the doctor should recommend him/her temporary abstention from reproduction. Introduction of radiopharmaceutical preparations to pregnant women with the purpose of diagnostics and therapy is not supposed. At introduction of radiopharmaceutical preparations to breast feeding mothers with the purpose of diagnostics or therapy breast feeding should be temporarily suspended. The terms of breast feeding termination depends on a kind and quantity of preparation used and is defined by separate instructions.

Protection of patients at radiological researches. The principle of normalization is realized by establishment of hygienic specifications (allowable limits of doses).

For practically healthy persons the annual effective dose of preventive medical radiological procedures and scientific researches should not exceed 1 mSv.

The principle of substantiation of radiological researches is realized in view of the following requirements:

- priority use of alternative (not radiating) methods;
- carrying out of X-ray researches only under clinical indications;
- choice of the most sparing methods of radiological researches;
- the risk of radiological research refusal should exceed obvious risk from irradiation itself.

When the accumulated dose of medical diagnostic irradiation of the patient comprises 500 mSv specific measures on further restriction from irradiation should be taken if radiological procedures are not dictated by vital indications.

If patients receive more than 200 mSv of the effective irradiation dose per year, or accumulated dose is more than 500 mSv from any irradiation source, or 1000 mSv from all the sources of irradiation the special medical inspection should be organized by public health services.

The dose of radiation received by the patient is influenced by following factors:

- Correct position during radiography. For example, the picture of the skull in a front-back projection causes 50-100 dose on a crystalline lens of the eye in comparison with a hind-forward projection.
- Collimation of X-ray beams.
- Sensitivity of the screen, amplifiers and detectors of the image.
- Combinations: a x-ray film - the screen strengthening have the major value. Now the strengthening foil containing materials from group rare-earth of metals (for example, gadolinium lanthanum) is standard. It is (at identical image sharpness) more sensitive, than a foil from tungstate calcium.
- Digital systems considerably reduce a dose of radiography.
- Use of image preservation (during researches and surgical interventions). Introduction of hardware-software complexes on processing and archivings of videoimages allows to lower a dose of irradiation of patients considerably.
- Usage fluoroscopy with imaging intensifier. This technology helps to reduce the dose (see tab. 4.2).

Radiation protection of the personnel during radiology researches.

The personnel who works with sources of radiation directly or is in a zone of radiation (for example, the nurses supporting small children) is most subjected to irradiation.

Following rules should be obeyed to protect medical personnel:

1. Performing radiological researches it is necessary to work quickly and limit a beam of radiation by a diaphragm.
2. To use protective clothes.
3. To be on sufficient distance from sources of radiation.
4. The great value has definition of indications, a choice of a method and algorithm of research.

Are very important for maintenance of radiating safety of the device of the signal system and the signs on safety warning the personnel and patients that the given room carries out radiological research and the x-ray machine works.

Protection of the personnel is provided, first of all, by shielding and reduction of stay time in a zone of irradiation. The personnel should limit the radiation beam by a diaphragm as much as possible, use standard protective means: screens, aprons, skirts, gloves.

Reduction of irradiation time is achieved by thorough training before a research, a choice of an optimum method, reduction of time of the research, careful selection of the patients subject to inspection.

Radiation protection of patients in nuclear medicine.

Nuclear medicine procedures are connected to a small dose radiation, unable to cause non-stochastic radiation lesions, however, as well as in x-ray diagnostics, the probability of stochastic effects is not excluded.

As well as in x-ray diagnostics the regulation of doses for patients and personnel is carried out in nuclear medicine. However protection of patients on the basis of physical principles of protection from ionizing radiation in conditions of nuclear medicine « in vivo » diagnostics is possible only due to reduction of entering in an organism radionuclides quantity.

Decrease of doses is achieved by use of modern hardware and methodical opportunities while preserving necessary diagnostic information. So, sodium iodine (Na^{131}I), causing rather important dose influence, is not practically used in diagnostics. Contra-indications for carrying out of nuclear medicine researches are specified above.

Radiating protection of the personnel in nuclear medicine. Radiating protection against external irradiation. At storage, packing and introduction of radiopharmaceutical preparations in quantity of several tens of MBq the doses received by the personnel from external irradiation, can appear high.

Protection against external radiation of open radioactive sources should be provided not only when packaging, but also in wards with patients to whom

radionuclides are injected in the medical purposes. The choice of means of protection depends on many factors, the main of which are: 1) physical characteristics of radiation; 2) time of radiation action to personnel; 3) distance between a source of radiation and a workplace; 4) a degree of shielding and radiating properties of a protective material. All these factors allow to calculate and carry out radiation protection of the personnel against external radiation in practice and help not to exceed the basic dose limits. Principles of radiation protection follow from the listed factors: protection by time, distance, shielding and quantity.

Radiating protection against internal irradiation.

A problem of protection from internal irradiation is more difficult, than from external as when radionuclide is inside an organism, it is practically impossible to change conditions to amplify protection.

Radionuclide quantity, arrived in an organism, as well as the ways of its distribution, depend on factors, in particular, on activity of preparation, character of the works, use of protective adaptations, observance of requirements of radiation safety and the organization of a sanitary - radiation control. Rules regulate quantity of radionuclide activity on a workplace (protection by quantity). Distribution of radioactive substances in the environment is warned by protective actions which basic purpose is not to allow uncontrolled radionuclide distribution in a zone of personnel presence. These actions are: automation of operations with open sources, use of the hermetically sealed protective chambers, containers and use of self-defense means.

The complex of protective measures during the work with open radioactive substances should provide prevention of air pollution, working surfaces, integuments and clothes of the personnel in working and adjacent rooms. Protective measures should be also applied against possible pollution of the environment - air, water and ground.

Basic preventive actions on maintenance of radiating safety of the personnel working with open radioactive sources are:

1. Placing and planning of premises.
2. Buffing of premises.
3. Protective and additional devices.
4. Rational systems of ventilation and water drain.
5. Gathering and removal of radioactive waste.
6. A choice of technological modes.
7. The rational organization of workplaces for personnel.
8. Observance of personal hygiene rules.

Requirements to buffing of premises. Walls and ceilings of premises should be covered with special non-adsorbing materials. Floors should be covered with non-adsorbing materials, for example, plastic compounds. For convenience the corners must be round to make cleaning easier.

In rooms intended for working with radionuclides a set of shields provides protection against external radiation. For each manipulation with open radioactive sources it is necessary to have special equipment corresponding to a kind of the used radionuclide and its activity. This equipment should include mobile shields, toolkit (a nipper, holders, tweezers), trays, pallets, ditches, etc. Tools for remote actions and local shielding provide reliable enough protection against external radiation of radionuclides.

The equipment and working furniture should have smooth surfaces, a simple design and non adsorbing coverings for facilitating the washing. Sinks for washing of the polluted utensils and toolkit as well as washstands should be supplied with cranes with cubital or pedal management. Washing of toilet bowls in toilets is carried out by pedal descent of water.

At the organization of workplaces of the personnel the equipment and remote tools should be carried out in view of zones of availability for working and of rational working poses on the basis of anthropometrical and psychophysiological parameters. The equipment, utensils and tools in working premises should be marked. In working rooms with open radionuclides the following is forbidden: stay of the personnel without necessary individual protective means, foodstuff, tobacco products, drink, smoking, cosmetic accessories, domestic clothes, and other subjects not connected with work.

CAPTER 5. MUSCULOSKELETAL IMAGING

5.1. Technical considerations of X-ray examinations of musculoskeletal system

The radiological method takes the leading role in diagnostics of damages and diseases of the skeletal system. If damage or disease of the skeleton is suspected the radiography is necessary. Radiography is the basic method of bones and joints examination. Radiography of skeleton bones and extremities take approximately 20-30 % from all diagnostic radiographic examinations in the world. According to some data, more than 80 % of bone lesions are detected, and almost in 70 % correct interpreting of the detected changes is possible. At first the plan film of a bone (joint) in two mutually perpendicular projections is performed.

Preparation for an X-ray examination.

Special preparation usually is not required. In an acute trauma of extremities splints are not an obstacle, therefore they are not removed. Plasters and ointments are removed.

Pelvic and lumbosacral department of a backbone.

Cleansing enemas are used 3-4 hours before a bedtime and immediately 1-1.5 hours before the procedure. Films are carried out on an empty stomach. Contraindications are absent, except shock and terminal state demanding urgent medical care. Sometimes common radiography cannot give answers to all the questions of clinic what conditions the application of additional techniques.

Restrictions of radiography:

1. Low specificity: it is impossible to distinguish directly non-mineralized tissues: osteoid, bone marrow, granulation, tumoral or fibrous tissues.

2. Low sensitivity to pathological changes of soft tissues elements.

Linear tomography is the important additional technique of bones and joints examination which gives the opportunity to receive the image of bone separate layers.

Tomography has the particular importance in examination of those skeleton parts which have a complicated configuration.

Computerized tomography (CT) allows to reduce sphere of linear tomography application considerably.

Indications for CT:

1. Detection of soft tissues components of osteal lesions and specifying of anatomic peculiarities of extremities, pelvic bones and a backbone lesions. Detection and exact localization of muscles lesions.

2. Estimation of changes in density of spongy bones structure and detection of mineral salts percentage in bones.

3. Detection of fractures in bones of extremities, backbone and pelvic bones, especially without dislocated fragments.

4. Estimation of the results of chemotherapy or radiotherapy and detection of their complications.

Direct image magnification is a technique of reception of enlarged X-ray films due to change of distances: focus, object, film. Shadow details on this X-ray films are characterized by their enlargement what is important for estimation of small elements of bone structure.

Arthrography is the research of joints with application of contrast agents (oxygenium, air, water-soluble contrast agents).

This technique specifies the diagnosis of intraarticular elements condition, for example, in a knee joint - meniscuses, cruciform ligaments.

Fistulography is contrast researches of sinus tracts in some skeletal diseases: osteomyelitis, tuberculosis. Sinus tracts are filled by oil-soluble contrast agents and then common X-ray films are made (fig. 5.1).



Fig. 5.1. Fistulogram of hip areas. Deformation and osteosclerosis of femur diaphysis. The ring form of sinus tract is defined. Chronic osteomyelitis of the femur.

Angiography (fig.5.2) can benefit diagnosing and definition of approach of patient care in following cases:

- occlusion or rupture of the artery after trauma;
- vessels thrombosis;
- formations of presumably vascular origin in soft tissues;
- arteriovenous malformation;
- initial tumours of bones if operative treatment is planned after a course of chemotherapy;
- deformations of extremities, including fingers; development of operation tactics.

Digital subtraction makes angiography more convenient and less invasive. The basic disadvantage of the given method is the fact that it doesn't visualize small vessels as opposed to angiography.

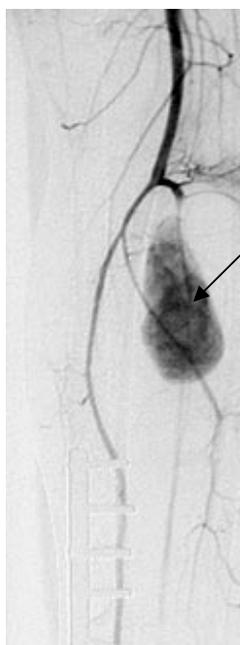


Fig. 5.2. Digital subtraction angiogram of the lower extremity. Pseudo-aneurysm in the anterior tibia artery area is defined (arrow).

Fluoroscopy. This method with its small resolving power and rather large radiation exposure should be applied for musculoskeletal system examination only in desperate situations, for example, in the some interventional radiology operations such as removal of foreign bodies, etc.

General applied radioanatomy of musculoskeletal system. Technique of bones radiography. In examination of extremities a film should cover two nearby joints; the suspected bone area should be in the center of the cassette, i.e. where the central beam is directed. Fixation of the filmed area is an indispensable condition of filming, insignificant motion causes blur of a pattern.

Technically well done image is such radiography which depicts thin structural (trabecular) a bone pattern well, and the bone looks like white light shadow on the grey background of soft tissues.

The radiograph gives sharp image of bone tissue, its inorganic part consisting of salts of calcium and phosphorus. Soft tissues in physiological conditions do not give the structural x-ray image, though radiography can detect tumours, calcifications, changes of the form and the sizes (fig. 5.3), contrast foreign bodies in soft tissues.

Diagnostic opportunities of X-ray method in osteology depend on anatomy-morphological substratum of pathological process in osteal and surrounding tissues.

On a plan X-ray film the precise image of osteal tissue is present; inorganic parts of a bone consisting of salts of calcium and phosphorus are seen on an X-ray image, while organic components of a bone do not make up a shadow. Thus, if process is connected to destruction of mineral structure of a bone, radiological diagnostics is substantially facilitated and, on the contrary, in presence of pathology of an ossiform tissue without salts radiological opportunities are restricted.

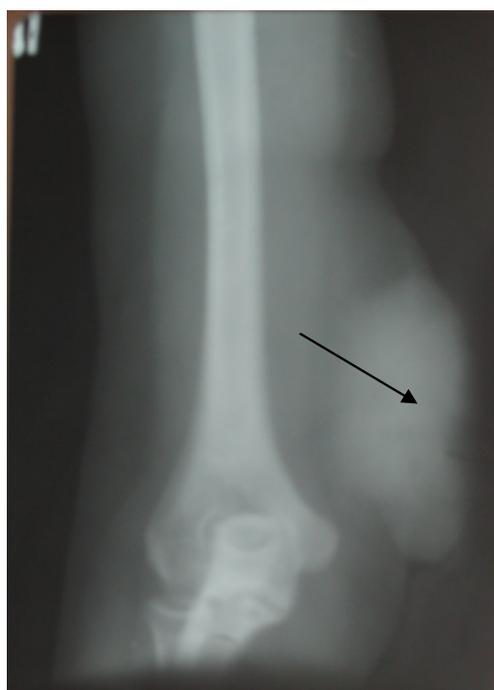


Fig. 5.3. Enlargement X-ray film of the shoulder in a direct projection. pathological mass corresponding to soft tissues on density is situated in soft tissues in the bottom third of the shoulder. It has a form of an irregular oval with sharp contours (arrow). A tumour of shoulder soft tissues.

From the point of view of radiological method, the whole skeleton consists of three structures: compact bone, spongy bone, structures without osteal elements.

Furthermore, a bone may be of two architectural types: compact (dense) bone or cancellous (spongy) bone. The distribution of these types of bones depends on load to which each bone is subjected.

There are three locations within a bone: the epiphysis, or growth center; the metaphysis, an area that lies just beneath the physis, or growth plate; and the diaphysis, or shaft. These locations are of considerable importance in predicting the nature of some bone lesions.

The form and the sizes of a bone caused by a functional orientation of this or that part of the skeleton depend on prevalence of this or that structure. Anatomically and morphologically the compact bone consists of skintight osteal trabeculae between which intertrabecular space filled by soft tissues practically is absent.

Therefore, the X-ray image of a compact bone is represented as surrounding a bony thready tissue forming the external contour of a bone. The compact bone presents in the cortical layer.

Spongy, or spongiform, the bone anatomically consists of osteal trabeculae, posed on the certain distances from each other. Between them the red bone marrow (soft tissues which is a part of a bone) is situated.

The X-ray pattern of a spongy bone rather typical and is characterized by reticular trabecularity with structure depending on anatomic-functional orientation of each bone. Structure without osteal elements in a skeleton are bone marrow canals in long tubular bones, apertures or spaces through which vessels of a bone pass; cartilaginous lines in metaepiphyseal departments, air sinuses and the whole system of articulate space – all these structures are depicted as lucent zones of the various shapes and sizes in X-ray film.

X-ray pattern of long tubular bones. As it is known, each long tubular bone consists of a diaphysis, two metaphyses and two epiphyses: proximal and distant metaepiphyses. Each department has a characteristic X-ray pattern. The diaphysis on a X-ray film (negative) is presented as two dense stripes of a compact bone (cortical a layer) which in the central part of the femur of an adult person can achieve 1 sm.

The compact bone in the field of metaphyses becomes extremely thin and in epiphyses is defined as a thin thready stripe.

Bone marrow canal passes along the diaphysis as a light stripe.

Metaphysis is the part of a long tubular bone located between the diaphysis and the epiphyseal line of the epiphysial plate. Its X-ray image has plexiform structure with larger cells, than in epiphyses.

Epiphyses are terminal parts of the bone which are located behind the epiphysial plate of a cartilage suture (in adults); epiphysis is an articular end of a bone.

Short bones of the skeleton. Their X-ray pattern in general is identical: as a whole the whole bone consists of spongiform substance and is zonated from different directions by a thin plate of a compact bone.

Flat bones - breastbone, the skull, the rib, the scapula, pelvic bones. They have the common X-ray pattern, expressing that between stripes of the compact bone there is a spongiform bone with trabecular reticular structure. Skull bones differ: the compact bone (external and internal plates) is rather thick, the diploe between them has another image, in comparison with a spongy bone in other bones.

Joints. Anatomically the joint represents intermittent, cavitary, mobile bond. The most part of articulate elements has soft structure so the direct display in an X-ray is not possible. Rontgenologically only two articulate components are displayed: the articulate bones end and the articulate space. Articulate end of each bone has strictly certain form and structure corresponding to function of a joint. In an image the articulate ends have precise contour and are zonated by well expressed equal "smooth" compact osteal plate. Cortical layer, localizing under articulate cartilage, is the closing plate.

The joint space is expressed on X-ray film as a stripe of clarification with the form projectively corresponding to articulate cartilages, disks, meniscuses and intraarticulate ligaments, as well as a true anatomical joint space. For each joint the X-ray joint space has certain height and the form. In children the joint space is wide, while in elderly people it is narrow due to cartilage deterioration. The widest joint space is located at knee and femoral joints (4-6 mm). For a healthy joint complete conformity of articulate surfaces is obligatory (fig.5.4).



Fig. 5.4. The radiography of a knee joint in direct and lateral projections. The radiography belongs to an adult. Stripes of shadows of metaphysis-epiphysis zones in the bones forming a knee joint are detected. Norm.

Age features of the skeleton

A bone of a newborn sharply differs from a bone of an adult. An X-ray film of a newborn displays only calcified diaphyses; cartilaginous epiphyses, as well as all small bones, are not discernible, except distal femoral epiphysis and calcaneal, astragaloid and cuboid bones ossification of which begins at a uterine age. Presence of the specified calcifications is a sign of fetus maturity.

In connection with a child's growth gradually ossification centers in epiphyses of long tubular bones and other, including, small bones appear. Until complete ossification, the light stripy will be detected between the epiphysis and the body of a bone. It is a cartilaginous layer, so called epiphyseal zone, or epiphyseal line.

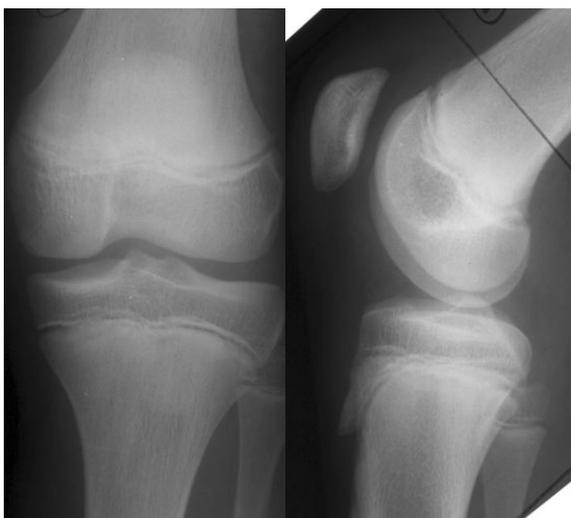


Fig. 5.5. The radiography of a knee joint in direct and lateral projections. The radiography belongs to a child. Zones of metaphysis-epiphysis cartilages in the bones forming a knee joint are detected as stripes of clarification. An ossification kernel is observed in the area of tuberosity of the tibia. Norm.

There are tables which help to define rather precisely the age of a growing organism on the basis of centers of ossification occurrence and accretion of the epiphysis with the metadiaphysis.

The younger is the person the wider is the epiphyseal line. It is limited from the epiphysis by the bone lamella surrounding the epiphysis spongiform substance by basal zone of ossification. From the metaphysis area it is limited by spongiform substance - dense osteal shaft known as a zone of a preliminary calcification.

Thus, X-ray film of bones and joints in children is characterized by following features: 1) ossification centers of epiphyses; 2) presence of a growth plate; 3) presence of larger articulate space.

The final synostosis of epiphyses with diaphyses occurs at 24-25 years, in women 2-4 years earlier; on a place of the epiphyseal zone X-ray for a long time detects more radiopaque lines known as epiphyseal cicatrix.

5.2. Radiography changes of bones and joints

The plan of studying of bone (joint) X-ray is rather simple. At first it is necessary to estimate a position, form and size of the bones displayed in images. Then it is necessary to consider contours of external and internal surfaces of cortical layer along the whole bone. After that it is necessary to investigate a condition of osteal structure in all sections of a bone. If X-rays are made to a child or teenager a condition of growth plate and ossification centers (terms of their occurrence, symmetry of ossification, terms of synostosis) should be found out. Ratio of the articulate ends of bones, size, shape of an X-ray articulate space, outlines of epiphyses end-plates are studied. Finally, it is necessary to establish volume and structure of soft tissues surrounding a bone.

The X-ray pattern of a bone change in any pathological process consists of the following components: change of structure, shape, volume, size, contours of a bone and surrounding tissues.

The set of symptoms accompanied by decrease of bone substance:

The basic and most common radiological sign in bone diseases is osteoporosis. Osteoporosis, or bone loss, is the decrease of osteal substance without change of volume, i.e. decrease in amount of osteal tissue per volume unit of a bone. Thus thickness and quantity of osteal beams decrease. In osteoporosis bone sizes remain without changes.

At the same time dynamic equilibrium of osteal tissue metabolic processes results in negative final balance. In osteoporosis each osteal beam contains normal

quantity of mineral salts as their accumulation and connection with an organic matrix is adjusted by the physical and chemical laws retaining the force during osteoporotic reorganization.

Osteoporosis in the X-ray image is characterized by the following signs: 1) occurrence of reticular structure of bone pattern arising because of thinning and destruction of separate osteal beams and augmentation of medullar cells volume; 2) thinning of the cortical bone layer, caused by destruction of osteal beams on the part of the bone marrow canal; 3) expansion of the bone marrow canal due to thinning of the cortical layer on the part of the bone marrow canal; 4) spongy cortical layer because of partial destruction of osteal plates; 5) sharply emphasized cortical a layer of the whole bone (fig. 5.6).



Fig. 5.6. The survey radiograph of bones of the forearm. Fracture in the area of bones of the forearm with angular displacement of fracture fragments. The divergence of fragments of the radial bone, caused by absence of the bone tissue in fragments ends adjoining to a line of fracture is observed. Osteoporosis of the wrist bones. Symptoms of the radial bone traumatic osteolysis.

The osteoporosis should be distinguished from destruction in which osteal beams disappear absolutely. According to a shadow character display osteoporosis can be: focal, nonhomogeneous osteoporosis (spotty, skewbald) and homogeneous (diffuse).

Nonhomogeneous osteoporosis as the remote islands is observed more often in acute processes: neuritises, fractures, phlegmons, combustions, frostbite and frequently it is an initial phase after which diffuse osteoporosis occurs.

Homogenous (diffuse) osteoporosis is observed in chronic, long processes. According to localization osteoporosis can be: 1) local – around the center of a lesion;

2) regional, embracing the whole anatomic area (joint); 3) wide-spread (the entire extremity); 4) systemic (the entire skeleton).

Atrophy. Atrophy is the decrease of volume of the entire bone or its part. Depending on the reason following types of atrophy are distinguished: a functional (from a divergence), neurotrophic, hormonal and an atrophy arising from pressure (fig. 5.7). Atrophy, as well as osteoporosis is a convertible process. When its reason is eliminated the osteal structure can be restored completely.



Fig. 5.7. Enlargement X-ray film of the shin in a direct projection. In area of proximal metaphysis of tibia there is a pathological shadow with distinct, wrong contours, without periosteal reaction, causing deformation of tibia and soft tissues (black arrows). Fibula in the field of the above-stated shadow is in atrophy due to a pressure of the pathological mass (a white arrow). Tibia osteoma.

Destruction. Destruction (destructive process) of osteal beams accompanies with inflammatory and tumoral processes in which a bone is replaced by a pathological tissue. According to the destructive center the osteal drawing on a film is absent (fig. 5.8).

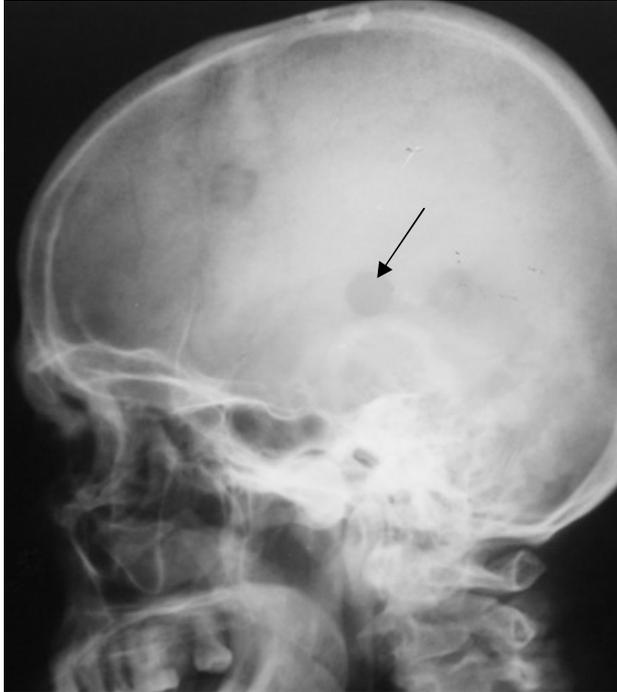


Fig. 5.8. The survey radiograph of the skull in a lateral projection. Sites of destruction have roundish form with accurate contours in bones of the skull arch (arrow). Myeloma (a tumour derived from cells in bone marrow).

Ossifluence. It is a pathological process accompanied by bone resorption in which the osteal tissue disappears completely with absence of reactive changes in surrounding tissues and the rest of a bone. The ossifluence is characteristic of some diseases of the central and peripheral nervous system, as for example, myelosingosis, tabes, wounds of the spinal cord and large nervous trunks. Traumatic ossifluence is possible (fig.5.6).

Osteomalacia. Its essence is "ramollissement" of bones due to an insufficient mineralization of osteal beams. This condition occurs as a result of bone reorganization when reformed ossiform beams are not impregnated with salts of lime. Development of such a condition is connected with endocrine disorder and nutritional factors, first of all, with failure of vitamin D. X-ray detects increasing and sharply expressed systemic osteoporosis especially in pelvic bones and long tubular bones of the lower extremities (fig. 5.9). The ramollissement of bones conducts leads to the arcuate curvatures of long tubular bones arising as a result of physiological stress and pull of muscle.

Thus the processes accompanied by decrease of osteal tissue amount are: 1) osteoporosis; 2) destruction; 3) ossifluence; 4) atrophy; 5) osteomalacia.



Fig. 5.9. Survey radiograph of shin bones in a child of 3,5 years old in a direct projection. Bones of the shins and visible departments of femurs are highly transparent (osteoporosis). Zones of preliminary calcification in all visible bones are expanded. Closing plates of metaphyses are not totally distinct. Femurs are deformed, bent inside. Metaphyses of shin bones and femoral distal metaphyses are expanded.

Radiological symptoms of rickets.

The sets of symptoms accompanied by augmentation of osteal tissue amount are: 1) osteosclerosis; 2) periosteal stratifications; 3) hypertrophy; 4) heterogeneous ossifications.

Osteosclerosis.

It is a process characterized by augmentation of osteal tissue amount in a unit of a bone volume. Thus the volume of each osteal beam and their quantity increases and, accordingly, spaces between beams decreases, down to their complete disappearance.

Radiological signs of osteosclerosis are: 1) reticular structure with small cells and thickened osteal beams down to complete disappearance of spongiform bone pattern; 2) thickening of the cortical a layer on the part of the bone marrow canal; 3) narrowing of the bone marrow canal down to its complete disappearance (fig. 5.10). Osteosclerosis can accompany various pathological processes: tumoral, inflammatory, hormonal disorders and poisonings, formation of osteal callosities and functional overloads. In any pathology osteosclerosis is a result of increased osteogenic activity of osteoblasts. Osteosclerosis can be a convertible process.



Fig. 5.10. Enlargement X-ray film of the left shin in direct and lateral projections. Extensive zones of destruction in proximal metaphysis and in diaphysis of the tibia. Evident osteosclerosis around the centres of destruction. Osteoporosis of the articulate ends of bones of a knee joint.

Chronic osteomyelitis of the left tibia.

Periosteal reactions. They are still named periostites and periostoses. Normally periosteum is not visible in an X-ray image. It occurs in periosteum thickening in case of its calcification.

Linear periostitis (laminated solid periosteal reaction). X-ray detects a thin linear shadow separated from a body of a bone by a radiolucent interval. This shadow is parallel to a shadow of a bone cortical layer. The linear periostitis indicates the beginning of inflammatory process, more often hematogenous osteomyelitis, or exacerbation of chronic inflammation. Calcification of periostitis in an acute hematogenous osteomyelitis begins on the 7-8th day of the onset in children, and on the 12-14th day in adults (first clinical signs) (fig. 5.11).



Fig. 5.11. The radiograph of the right femur in a direct projection. In diaphysis area linear periosteal reaction is defined (arrow). Sites of destruction are in the field of diaphysis (arrow with rombus). Radiological symptoms of acute osteomyelitis.

Irregular interrupted periosteal reaction. X-ray shows that there are some alternating light and dark stripes along a bone, as if emanating from one point and located one under another. In the basis of this phenomenon is indulating jerky character of the development process, which is more common in Ewing tumors and less frequently in inflammatory diseases (fig. 5.12).



Fig. 5.12. Enlargement radiograph of a patient's femur with Ewing's sarcoma. Irregular interrupted periosteal reaction (arrow) is defined

Assimilated periostitis - the subsequent phase of a laminated solid periosteal reaction (linear periostitis) when there is a connecting of calcifications with a basic bone (fig. 5.13).



Fig. 5.13. Enlargement radiograph of the left shin in direct and lateral projections. Fibula is deformed and enlarged due to osteosclerosis and assimilated periosteal reaction (new bone formation). Chronic osteomyelitis of fibula.

Spiculated-type periosteal reaction. It manifests as a formation of numerous thin processes (spiculae), growing at an angle to the diaphysis. These needles are ossification of newly formed tissues along the blood vessels. It is common in osteosarcoma (fig. 5.14), sometimes in metastasis (fig. 5.15).

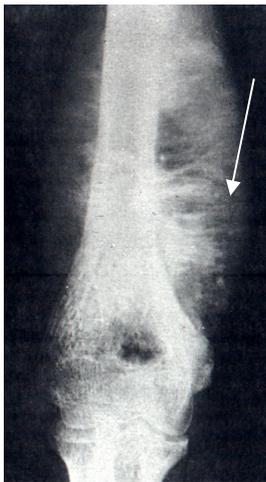


Fig. 5.14. Enlargement radiograph of the shoulder in a direct projection. Evident spiculated-type periosteal reaction in distal metaphysis and diaphysis of the lower third of the humerus (arrow). Osteogenic sarcoma of the humerus.



Fig. 5.15. The radiograph of a humeral joint in a direct projection. In the middle and the humeral end of the clavicle there is spiculated periosteal reaction (arrows). Prostate cancer metastasis in the clavicle (the diagnosis is verified by hystological examination).

Ossifying periostosis as «Codman treangle». Its essence lies in the fact that tumoral process in the middle of a bone, invading the cortical layer, removes the periosteum in which reactive changes such as ossifying periostitis occur. Most frequently occurs at an osteosarcoma (fig. 5.16).

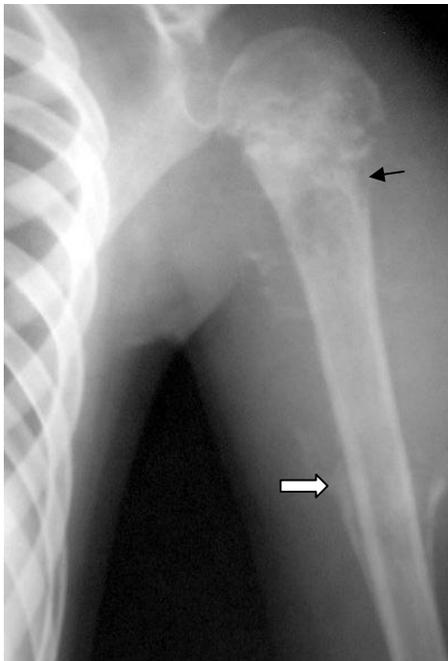


Fig. 5.16. Enlargement radiograph of the humeral bone in a direct projection. In proximal metaphysis area of the humerus there are extensive sites of destruction with indistinct contours and destruction of the cortical layer (arrow). There are periosteal reaction in the upper third of the diaphysis – Codman's triangle (a figured arrow). Osteogenic sarcoma of the humeral bone.

Hypertrophy. This phenomenon is opposite to atrophy. It is characterized by augmentation of volume of the whole bone or its part.

Heterogeneous ossifications. This term is used to denote osteal formations locating close to the bone and developed not from the periosteum, but from soft tissues surrounding the bone, such as fascias, tendons, ligaments, hematomas, etc. (fig. 5. 17). They can occur due to various reasons, including traumas, increased functional loads, dystrophic processes.



Fig. 5.17. Enlargement radiograph of the humeral joint in a direct projection. In the area of the humeral joint there is an intensive shade in a sinew projection of the supraspinatus muscle (arrow).

Calcification of the sinew supraspinatus muscle.

Necrosis and sequestration of a bone.

Osteonecrosis is a necrosis of part of the bone due to trophism. Pathomorphologic basis of osteonecrosis is destruction of osteal cells despite retention of dense intermediate substance. In osteonecrosis connective layer consisting of soft tissue develops on the border between a necrotic site and the surrounding bone. This layer separates necrotic fragment of the bone from the living areas. The lifeless site separated from the basic bone refers to as sequester.

Septic and aseptic necroses are distinguished. Aseptic necrosis is observed in deforming arthroses, thromboses and embolisms.

Septic, or infectious necrosis occurs in inflammatory diseases. The X-ray pattern of osteonecroses is characterized by following signs: 1) the increased intensity of necrotizing bones; 2) lucid interval separating a healthy bone from the necrotic one; 3) osteoporosis of the surrounding healthy tissue (fig. 5.18).

According to the X-ray pattern it is rather difficult to distinguish aseptic osteonecrosis from septic one. Diagnostic criterion can be a boundary interval width

which is wider in the infectious process. Sometimes it is difficult to distinguish intensive osteonecrosis and osteosclerosis as well.



Fig. 5.18. Enlargement radiograph of the femur in a direct projection. The femur is deformed, increased, with osteonecroses signs: a cavity with sequester (arrow) surrounded with an extensive zone of osteosclerosis. Chronic femur osteomyelitis.

Criterion is the lucid interval which is characteristic of osteonecrosis. If this interval is narrow and is not detected, it is impossible to differentiate osteonecrosis and osteosclerosis.

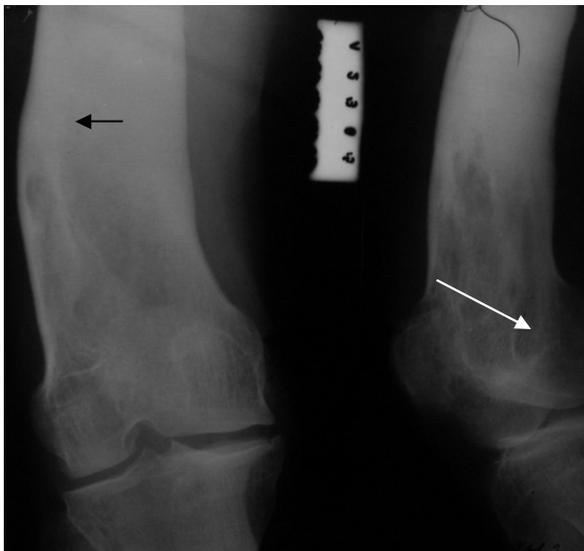
Changes of the shape of a bone. They can be various: arcuate in rachitis, angle after a trauma, S-shaped in congenital deformations.

Curvatures are classified according to degrees of manifestation: insignificant, significant, sharp with the indication of a curvature. Bone deformations include bone defects: partial or total (fig. 5.19).



Fig. 5.19. Enlargement radiograph of the femur in a direct projection. There is a leg amputation at the level of the middle third of the shaft of femur.

Change of a bone volume. Characterizing the volume swelling and thinning of a bone is meant. Thickening (hyperostosis) is osteosclerosis plus augmentation of a bone volume. Speaking about hyperostosis augmentation of a bone diameter at an appreciable extent is meant (5.20).



5.20. Enlargement radiograph of the hip in direct and lateral projections. Hyperostosis of the femur: the femur in the lower third of diaphysis (a black arrow) and distal epiphysis is deformed, densified (osteosclerosis), and increased in sizes. Sites of destruction in distal metaphysis (a white arrow) are detected as well. Chronic osteomyelitis of the femur.

Exostosis is enlargement of osteal tissue on the limited area, transcending a bone limits.

Enostosis is enlargement of osteal tissue aside the cerebral canal.

Inflation (swelling) of a bone – augmentation of a bone volume with decrease of osteal substance amount due to enlargement of pathological soft tissues substrate.

The last can be a cartilage in enchondroma, products of degenerative disintegration in cysts, giant-cell tumours, etc. (fig. 5.21).



Fig. 5.21. Enlargement radiograph of the forearm in a lateral projection. In ulna distal epimetaphysis there is increase in volume of the bone with cellular destruction and cortical thinning (arrow). Signs of periosteal reaction are absent. Osteoblastoma of the ulna.

Symptomatology of joints diseases

The basic and most common in such cases is narrowing of the articulate space or its complete absence that indicates destruction of articulate cartilages. Narrowing of the articulate space can be homogenous (on all an extent) and non-homogenous.

Complete absence of an articulate space with transition of osteal beams of one bone to another refers to as ankylosis. Ankylosis can be complete and incomplete (partial). Congenital absence of a joint (articulate space) can occur. In that case we speak about a concrecence which has typical localization – fine joints of extremities, vertebra.

Change of subchondral plates. It can manifest itself as increased intensity of its shadow that indicates compression in arthroses, osteochondroses vertebra or, on the contrary, thinning, break or complete absence that is the result of resorptions, infringement of integrity or fusion due to destructive process (tuberculosis of joints, purulent arthritis) (fig. 5.22).

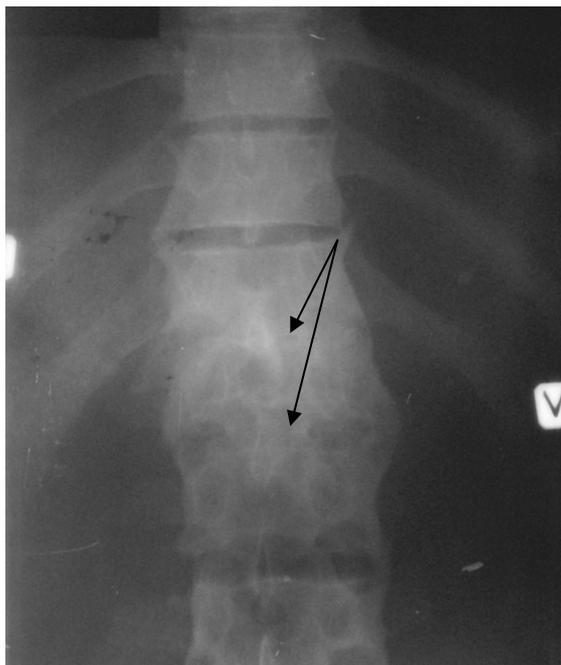


Fig. 5.22. Enlargement radiograph of lumbar and chest departments of the backbone in a direct projection. Ankylosis Th12, L1 and L2 of vertebrae (arrows) is detected.

Ankylosing tuberculous spondylitis of the backbone.

Destruction of articulate bone parts. This sign is characterized by destruction of bones localized within the limits of the articulate capsule and near to it outside the joint or under the closing plate (fig. 5.23).

Deformation of articulate ends of bones. As a rule deformation of the articulate ends and articulate surfaces is the basic sign of arthrosis. Deformation can look like: flattening of the glenoid cavity as well as articular head; recess of the glenoid cavity; excrescence on the edges of the glenoid cavity; elongations of closing plates in horizontal directions (fig. 5.24).



Fig. 5.23. The radiograph of lumbar part of the backbone in a lateral projection. There is a destruction of adjacent bodies L4-L5 of vertebrae. Puncture of the damage area detects needles.



Fig. 5.24. Radiographs of the knee joint in direct and lateral projections. Narrowing and deformation of the joint space, subchondral sclerosis (arrow), cysts formations (figured arrows), osteophytosis (a double arrow) are detected. Osteoarthritis of the right knee joint.

The maximum degree of deformation of articulate bone departments is infringement of normal ratio in a joint that underlies whole nosological unit – dislocations.

5.3. Bone scintigraphy

Advantage of bone scintigraphy is visualization of the whole skeleton. Therefore, if it is necessary to investigate some departments of the skeleton, bone scintigraphy is more favourable than radiography at which the radiation dose increases with augmentation of visualized areas. At systemic and plural lesions of the skeleton the scintigraphy as the initial method with the subsequent radiography of areas with increased accumulation of radiopharmaceuticals is indicated. With the introduction of ^{99m}Tc -labeled phosphorus compounds, a new dimension of safety and accuracy was accomplished. The phosphorus contained within the isotope is exchanged in areas of rapid bone turnover: destructive lesions such as osteomyelitis and tumors, arthritis, and areas of growing bone (fig. 5.25).

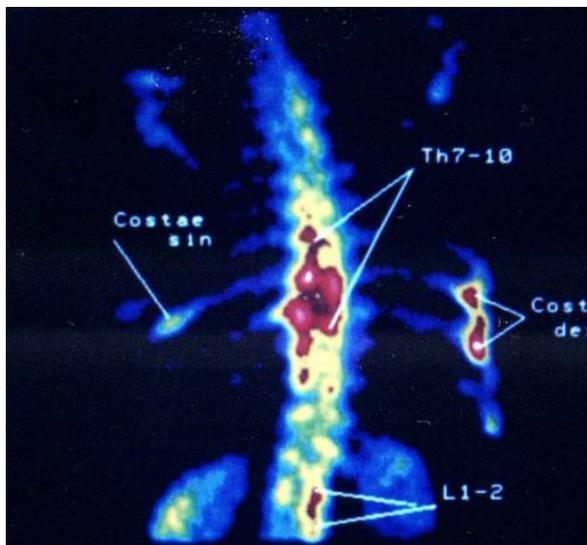


Fig. 5.25. Radionuclide bone imaging (osteoscintigraphy), with ^{99m}Tc -phosphonates. Hyperfixing in chest and lumbar departments of the backbone; in ribs from both parties. Signs of metastases of a malignant tumour in a bone.

Although the scan itself is not specific for a particular disease, it indicates an area of bony abnormality to which radiography, CT, and MR may be directed.

Thus, the basic indications for initial application of bone scintigraphy are: 1) clinically suspected plural and systemic lesions of the skeleton; 2) osteomyelitis in the first 10-15 days; 3) search for metastases in the skeleton at the fixed cancer diagnosis; 4) studying of the intensity degree of mineral exchange in general diseases of bones and joints; 5) definition of transplant functional suitability and their viability.

In all cases of osteotropic radiopharmaceuticals use it is necessary to consider the common factors influencing the amount of radionuclides absorbed by pathological process: vascularization degree, collagen quantity, bones ossification activity, depth and anatomic location of the center, complications (fractures), and duration of the

disease. For tumours these factors are: growth degree and presence of a necrotic component.

Normally 3-4 hours after radiopharmaceuticals introduction subsequent to proportional distribution of ^{99m}Tc - phosphonates in bones a lot of areas of the increased accumulation are indicated: skull base, ribs, angles and edges of scapulas, vertebrae, pelvic bones, metaepiphyseal departments of tubular bones. Lesion centers are visible rather clearly.

5.4. Magnetic resonance imaging

MRI has advantages in comparison with radiography and CT providing better images of bone marrow tissues, but MRI is less efficient in evaluation of cortical layer of bones.

It is the most sensitive method of visualization of bone marrow lesions in patients with Chodgkin's disease and limphosarcomas, bone aseptic necrosis, osteomyelitis, cancer metastases, bone marrow edema.

MRI allows to estimate a bone lesion and simultaneously to reveal a soft tissue tumour component. Though the field of MRI use in many aspects coincides with scintigraphy, MRI is frequently more informative. Due to the high information content of MR images compared to radiographs it will probably become the second method in bone diseases diagnosing, supplementing X-ray films if necessary.

MRI is the best noninvasive method of joints visualization. It is the unique method displaying all the structural elements of joints and their pathological changes directly:

- exudate in the joint cavity;
- changes of synovial membrane;
- hyaline articular cartilages;
- intra-articulate structures consisting of a fibrous cartilage, for example meniscuses of knee joints;
- ligaments;
- subchondral bone marrow.

MRI is the most exact method of evaluation of these structures. For example, according to the published comparisons, X-ray filming detects 5-10 ml of exudate in the elbow joint, ultrasonic scanning - 1-3 and at MRI - 1 ml. MRI under certain conditions is the best method of articulate cartilages estimation, allowing to detect early stages of chondromalacia, articular cartilage erosion of inflammatory origin, defects and thinning in arthrosis, damages of cartilage labia of glenoid cavities.

In MRI with intravenous opacification a short (up to 15 min) stage of intensifying of rich vascularized intraarticate structures is replaced by transition of contrast agents (CA) in synovial liquid. Due to that the articulate cavity is better represented as well as its borders. Such arthrographic effect can promote diagnostics of some pathological changes in joints. MRI with intraarticate opacification (MR-arthrography) in many cases is considered to be the best method of visualization of articulate structures, especially if there is exudate in a joint.

However MRI performance is still not enough to display movements in real time. The majority of MR-tomographs at best can give only a series of images during different moments of this or that movement.

5.5. Ultrasonic investigation

To receive images of extremities it is recommended to use 5 or 7,5 MHz gauge. This method gives the helpful information for diagnostics of:

- neoplasms in soft tissues;
- accumulation of fluid in soft tissues;
- traumatic tendon and muscles injuries;
- intraarticate exudates;
- congenital hip dislocation;
- congenital or acquired vessel anomalies (in such cases Doppler ultrasound gives especially valuable information).

Ultrasonic research is useful also for specification of a needle position in biopsy, aspiration or fluid drainage.

5.6. Radiology at traumatic damages of a musculoskeletal system

Fractures and dislocations of bones.

Complete inconformity of articulate surfaces is called dislocation. This sign detected by X-ray, is accompanied by considerable dislocation of the central axis of one of bones in relation to another. Dislocated bone is the one which is located distally (fig. 5.26).



Fig. 5.26. The radiograph of the left ulnar joint in direct and lateral projections. Full discrepancy of joint surfaces of an ulnar joint due to dislocation of forearm bones with their displacement backwards.

In the backbone a dislocated vertebra is the overlying one. Reading X-ray images with this pathology of the skeleton, it is necessary to specify: 1) shift direction of the dislocated bone and 2) the degree of its expressiveness in centimeters or in relation to the sizes of longitudinal axis and diameter of the fixed articular bone.

Partial disorder in relation of bones in a joint and partial inconformity of articulate or jointed bone departments is called subluxation.

Much more often traumatic bones lesions are accompanied by fractures (fig. 5.27 and 5.28).



Fig. 5.27. Enlargement radiographs of the shin in direct and lateral projections. In the area of distal metaphysis and epiphysis of tibia there is the line of fracture (arrows) located under a corner in a vertical direction, dislocation of the back tibia fragment backwards. Discrepancy of joints surfaces in the ankle joint (a white arrow). Intrajoint fracture of tibia back edge, dislocation of the foot backwards.



Fig. 28. The radiograph of the humeral joint in a direct projection. In the area of the surgical neck of the humerus fracture with cross-section displacement to lateral direction (on the width of metaphysis). Proximal fragment is displaced downwards. Total discrepancy of surfaces in the humeral joint. Fracture of the humeral bone surgical neck. Back dislocation of the shoulder.

Anatomic basis of fracture is an X-ray displayed plane of fracture: 1) a line of a radiolucent interval. Estimating the condition of contours and osteal structure in the area of a prospective plane of fracture, sometimes it is possible to reveal 2) a radiopaque line (fig. 5.29).



Fig 5.29. The radiograph of the hip joint in a direct projection. The line of fracture in the form of consolidated osteal tissue in the area of a femur neck (a black arrow) with a small fragment (a white arrow) is detected. Impaction fracture of the femur neck.

In this case bones are somewhat shortened, their contours are slightly deformed. Such kind of fracture is called an impacted one, or fracture with impaction fragment. Distal fragment is usually displaced along the longitudinal axis of a bone in proximal direction. Thus, besides a sign of a fracture line, there is still a sign of fragment dislocation. Roentgenologically fragments dislocation is characterized by their sizes, shapes and number detection. Dislocated fragment can be 1) lateral along a diameter of a bone (displacement), longitudinal in relation to longitudinal bones, and 2) divergent, overriding and impacted. Any dislocated fragment is analyzed according to direction and a degree of evidence: 1) lateral - in relation to diameter proximal fragment, 2) longitudinal - in centimeters 3) angular in degrees. Quite often typical traumas evoke so-called 4) peripheric or rotatory fragment dislocations. According to the direction of a fracture line to a bone axis following types are distinguished 1) transversal (displacement), 2) longitudinal (divergences fragment, overriding them and impaction), 3) spiral fractures and their various combinations. Fracture in many planes is called a comminuted one. If there are fractures of different localization within one bone we speak about a multiple fracture. In relation to a joint 1) intraarticate and 2) extraarticate fractures are distinguished (fig. 5.30, 5.31, 5.32, 5.33, 5.34, 5.35, 5,36, 5.37).



Fig. 5.30. CT-scan of the left hip joint. A fracture line in the area of femoral neck medial department (arrow). Fragments dislocations are insignificant: the bone contour is irregular along the fracture line.



Fig. 5.31. The radiograph of the humeral joint in a direct projection. A line of fracture and cross-section fragments displacement in the area of the clavicle body (arrow). Clavicle fracture is detected.



Fig. 5.32. The radiograph of the knee joint in a lateral projection. A fracture line in the patella and a longitudinal divergence of fragments (arrow). Fracture of the patella is detected.



Fig. 5.33. Enlargement radiograph of the femur in a lateral projection. Spiral fracture of the femur diaphysis is detected.



Fig. 5.34. Enlargement radiographs of the shin in direct and lateral projections. Spiral lines of fracture in the tibia and fibula diaphyses are detected. Displacement of bone fragments in a cross-section direction. There are additional bone fragments in the affected area (white arrows). The image depicts wire transport splint in a lateral projection (a black arrow). Splintered tibia and fibula fractures are detected.

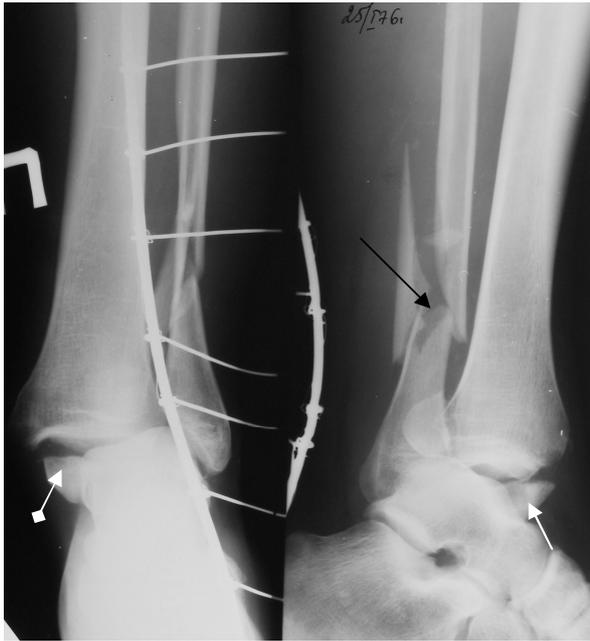


Fig. 5.35. Enlargement radiographs of the shin in direct and lateral projections. A fracture line in distal third of diaphysis area of fibula with a bone splinter (a black arrow). The internal ankle-bone fracture line is located diametrically (a white arrow). Ectad subluxation of the foot (white diamond-shaped arrow). Fracture of the internal ankle-bone (intrajoint) and splintered fibula fracture with lateral subluxation of the foot.

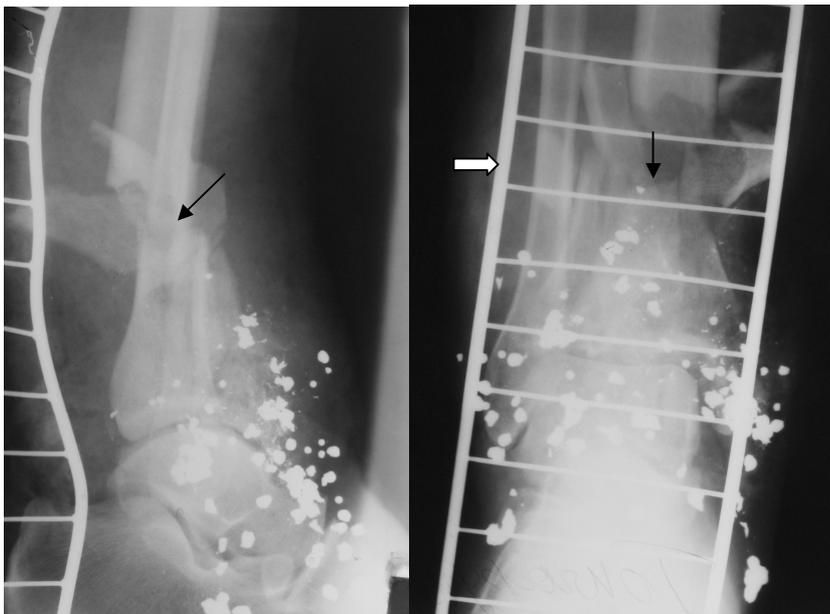


Fig. 5.36. Enlargement radiographs of the shin in direct and lateral projections. In the area of the ankle joint in both projections there are multiple small the round high-intensity foreign bodies (gun shot). Fracture lines in distal thirds of tibia and fibula diaphyses (black arrows), and also in distal metaphysis of the tibia. Numerous bone splinters in the area of the tibia lesion. A wire transport splint (a figured arrow). Fire fractures of shin bones: multisplintered tibia and transverse fibula fractures.



Fig.5.37. Enlargement radiograph of the hip in a direct projection. In a middle third of the femoral diaphysis there is an extensive nonhomogeneous area of destruction with indistinct contours; a fracture line, angular displacement of fragments (arrow).

Ewing's sarcoma of the femur. Pathological fracture of the femoral diaphysis.

Intraarticular fractures usually localize behind the place of joint capsule attachment, i.e. near an articular bone surface. A fracture line can penetrate into this area from outside as well. All the rest fractures are extraarticular. If the part of a bone is damaged and a fracture line does not reach an opposite contour then it is an incomplete fracture or crack (fig. 5.38).



Fig. 5.38. Enlargement radiograph of the right shin in direct and lateral projections. The line of fracture lies in tibia diaphysis area, extending from a front-exterior contour of a bone to backwards-interior one, not reaching an opposite contour (arrows). Displacement of fragments is absent. Incomplete fracture of the right tibia diaphysis is detected.

Healing of fractures proceeds through the formation of callus, which develops from the endosteum of the main mass of bone substance and periosteum. The most intensive reparative processes take place in periosteum. The first sign of callus formation is calcification. In children line depositions usually are detected on roentgenograms 1,5-2 weeks after a fracture, in adults in 3-4 weeks. Complete osteal consolidation occurs not earlier than in 3-7 months. Approximately at the same time

fracture line becomes invisible. The structure is restored completely; however a muff-like thickening as a result of the formed callus is preserved on the bone external surface, on the place of former fracture. Dynamics of fractures and their complications healing is evaluated with the help of radiography (fig. 5.39, 5.40).



Fig. 5.39. The radiograph of the elbow joint area in direct and lateral projections. The fracture line in the proximal diaphysis of ulna (a black arrow) is detected; displacement of fragments is not present. There is normal callus in size and form on the place of ulnar bone fracture (a white arrow).

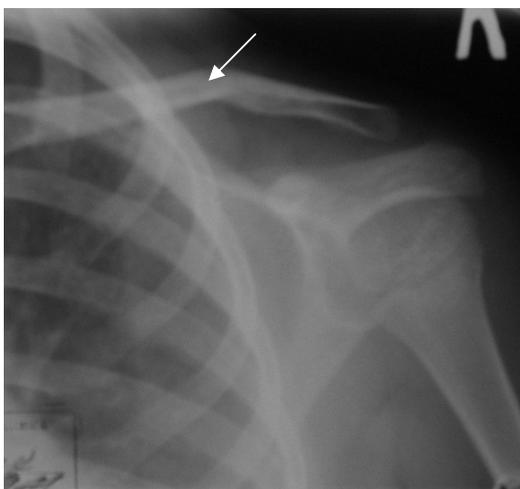


Fig. 5.40. The radiograph of the humeral joint in a direct projection. Fracture of the clavicle body with fragments displacement under a corner opened downwards (arrow). The line of fracture is not detected. A healing stage. Solid fracture of the clavicle body.

The radiological signs of fractures described earlier are characteristic of long tubular bones fractures. Short spongiform bones also have the same features, except the presence of bones configuration disorder fracture sign without displacement of fragments. For example, in compression fractures of vertebra bodies their clinoid deformation is detected (fig. 5.41). Thus the line of fracture in a spongiform bone is almost not detected; only careful studying of the trabecula and crossbeams condition will help to detect it.

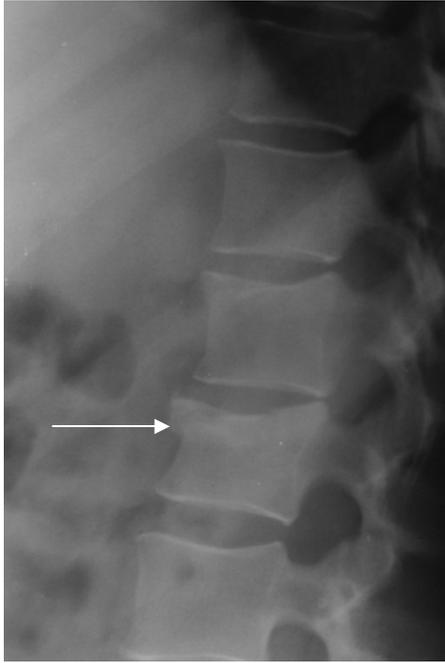


Fig. 5.41. The radiograph of lumbar department of the backbone in a lateral projection. Vertebra displacement is absent. Anterior compression of the body of the third lumbar vertebra is detected (arrow).

Flat bones may have a specific kind of a fracture line. Usually the fracture line in a compact part of a bone has distinct, small jagged contours. Deep in the spongiform osteal substance contours of a fracture line are less distinct large-serrated. Depending on the age of a patient fractures have different manifestation. Senile fractures are characterized by multiple lines of fractures, comminuted fractures, and slow osseous consolidation. Children's fractures have following features: a) arcuate fractures of the diaphysis due to multiple microfractures along the bone, causing arcuate deformation without the detected fracture line; b) subperiosteal fracture with distinct line of fracture and limited disturbance of bone contour smoothness of flatness of a contour of a bone, but without fragments shift. Special kind of children's fractures is allocated into a group of traumatic epiphyseolysis. Usually this term means the infringement of bone integrity in the area of the growth plate. Radiological detection is based on detecting the dislocation of the ossification nucleus in relation to a bone metaphysis (epiphyseolysis). Fracture of the bones shaft may be either complete or of the green-stick variety. Three types of green-stick fractures are recognized: classic green-stick (fracture on one side of the bone, bent on the other), "torus," resembling the base of a Greek column (buckling of cortex on both sides of the bone), and "lead pipe" (one side buckled, one side cracked). Of these, the torus variety is the most common (fig.5.42, 5.43, 5.44).



Fig. 5.42. Enlargement radiograph of the forearm in a lateral projection. Incomplete fracture of ulna diaphysis. The line of fracture does not reach cortical a layer along the back surface of the ulna (arrow). Ulnar and radial bones are deformed arcuately. Arcuate fracture of the radial bone and willow fracture.



Fig. 5.43. Radiograph of the radiocarpal articulation in direct and lateral projections. Consolidation of osseal structure of radial bone metaphysis and deformation of its surface (a white arrow). Torus fracture of radial bone distal metaphysis of radius.

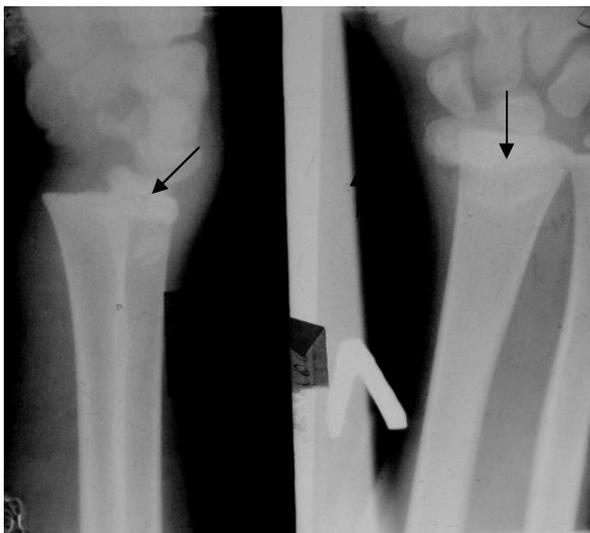


Fig.5.44. The radiograph of the left radiocarpal articulation in direct and lateral projections of a 14-year-old child. In direct and lateral projections there is a displacement of radial bone ectad and entad (arrows). Traumatic epiphysiolysis with radial bone distal epiphysis displacement.

Damage of soft tissues in bone fractures, dislocations and subluxations always accompany the basic pathological process, being detected on radiographs as various deformations due to hemorrhages and exudation of interstitial fluid; besides presence of small osteal fragments is possible as well as intermuscular hematomas muscles and ligaments calcifications.

Pathological healing of fractures are displayed by formation of incorrectly fused fracture, excessive callus, false joint, a bones synostosis or ossifluence of the injured department of bony skeleton (fig. 5.45).

In fractures and dislocations of bones the main method of radiological diagnostics is radiography.

Traumatic damages of soft tissues. Ultrasonic scanning has the greatest opportunities among radiodiagnostic methods in detection of muscle lesions.

Opportunities of ultrasonic scanning in muscle lesions:



Fig. 5.45. X-ray of shin bones in direct and lateral projections. Fracture edges near to a fracture line of tibia are condensed. Osteosynthesis in the form of metal staples, connecting tibia fragments is visible. A false joint in tibia (a black arrow) and incorrectly fused fracture in the distal fibula with well generated callus (a white arrow).

- visualization of stretchings and ruptures, intramuscular hematomas due to injuries, muscles atrophy due to inactivity and denervation;
 - control over partial breaks of muscles;
 - estimation of damages outcomes: cicatrices after extensive untreated myorrhexis, cysts due to focal ossifying myositis and muscular hernias.
- Ultrasound gives opportunity to observe changes of muscles shape during contractions in real time.

Tendon tears are detected roentgenologically only in sites of tendon attachment to a bone due to separation of osteal fragments. Ultrasound allows to detect damages along the whole tendons, to differentiate partial and complete tears and to localize the ends of retracted muscles. For example, practically all tears of Achilles tendon are detected.

Ligaments lesions. Series of methods are used. Functional radiography allows to detect them, for example, in radiocarpal and talocrural joints according to indirect signs – redundancy of physiological movements in a joint or occurrence of physiologically impossible movements. Functional ultrasound sensitivity is higher in detection of hand joint instability than radiography sensitivity.

MRI and ultrasonic scanning are ambiguous in diagnostics. In diagnosing of damages of ankle joint lateral ligaments MRI and ultrasonic scanning are practically equivalent, though opportunities of both methods are limited because of anatomic variants. In the area of the radiocarpal joint ultrasonic scanning considerably concedes to MRI and especially the MRI-arthrographies, allowing to visualize the majority of ligaments and to detect their damages.

MRI is a unique method of radiodiagnosis of bones injuries and local traumatic edema of bone marrow.

Tears of many ligaments are detected by arthrography.

5.7. Radiology signs of inflammatory bone lesions

1) Methods of choice in acute stage or exacerbations is MRI and bone scintigraphy; changes are visualized from the first days. MRI sensitivity (up to 98 %) is higher, than CT and scintigraphies. Its insufficient specificity (it is little more than 80 %) limits diagnostics taking into account clinical picture.

2) X-rays patterns are negative not less than 10-14 days from the beginning of a disease while only bone soft tissues (bone marrow and a periosteum) are affected. First of all roentgenologically it is possible to detect changes in soft tissues around bone, however in practice they are usually missed.

Early detection of purulent processes, for example, in the hip joint area, promotes prevention of rapid osteal destruction, improving the outcome.

Radiography is the basic method of visualization in subacute and chronic osteomyelitis. Osteonecrosis is detected usually not earlier, than a month after the disease beginning, and sequestration even later.

3) Changes of soft tissues are detected by ultrasonic scanning; subperiosteal abscesses detected. Ultrasonic scanning promotes earlier diagnostics in inaccessibility of MRI and scintigraphy.

4) CT a little bit earlier, than radiography detects inflammatory changes in the bone; it does not concede ultrasonic scanning in revealing soft tissues changes. In chronic osteomyelitis CT is better than other methods in visualizing sequesters and abscesses.

5) Activity of osteomyelitis in a chronic stage can be estimated by means of scintigraphy and CT earlier, than using X-ray which shows newly arisen osteal destruction and periosteal reaction. MRI surpasses all methods in this parameter, simultaneously detecting intramedullar diffusion of process and changes in soft tissues, including fistulas.

6) Fistulas can be detected by ultrasonic scanning, but the best method is fistulography.

In X-ray the radiological inflammatory bone lesion syndrome includes following signs: 1) the centers of destruction; 2) osteal sequesters; 3) periostitis; 4) bone loss (osteoporosis); 5) osteosclerosis.

In hematogenous osteomyelitis the earliest symptom on the 2-3rd day of the disease is tumescence and deformation of the soft tissues surrounding a bone. The first direct signs of osteomyelitis are periosteal stratifications (periosteal reaction) and osteoporosis. The initial signs of periosteal osteogenesis can be seen by the end of the 1-st week; during the same period osteoporosis is formed. On the 2-3rd week of disease the centers of destruction occur. If treatment is started on time, in the end of the 3rd beginning of the 4th week the process of endosteal osteosclerosis characteristic of an osteomyelitis will develop around the destructive centers. This process is characterized by diffusion and prevalence, what differs it from a narrow zone of osteosclerosis in tubercular osteitis. Sequesters are formed. Widespread osteosclerosis in osteomyelitis indicates the transition of process in chronic one; assimilated periostitis is characteristic of it as well (fig. 5.46, 5.47).



Fig. 5.46. Enlargement radiograph of the shin in a direct projection. The tibia is deformed and enlarged, symptoms of osteonecrosis are defined: equestral cavity with sequestration (arrow), surrounded by the extensive zone of osteosclerosis. Chronic osteomyelitis of the tibia.

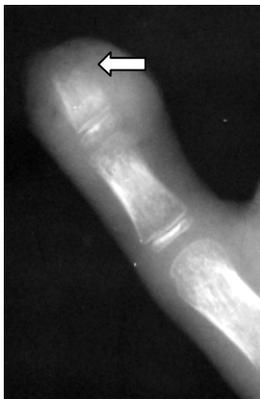


Fig. 5.47. Enlargement radiograph of the first finger of the hand. Osteoporosis, consolidation and increase in soft tissues in area of distal phalanx (a figured arrow) is indicated. It is destruction of a bone of distal phalanx of the first finger (arrow). Panaricium of the first finger of the hand.

In tubercular inflammation (a tubercular ostitis) the acute phase is stretched for many months. As a rule, process begins in the articulate end of a bone, where in a bone marrow the initial (in relation to a joint) tuberculous focuses (5.48).



Fig. 5.48. The radiograph of the knee joint in a direct projection. In area of femoral distal metaphysis there is a site of destruction with indistinct contours (arrow). Tubercular ostitis of the femur is indicated.

Diffusion of the joint inflammation has received the name arthritic one (5.49, 5.49); in the backbone inflammation of intervertebral disks and soft tissues is called spondylitic phase.



Fig. 5.49. The radiograph of the knee joint in a direct projection. In area of tibia proximal epiphysis a site of destruction with indistinct contours (arrow) is detected. There is a narrowing of the knee joint and its deformation. Subchondral sclerosis is detected. There is a marginal osteophyte (figured arrows). Tubercular osteitis of the tibia. Osteoarthritis of the knee is detected.

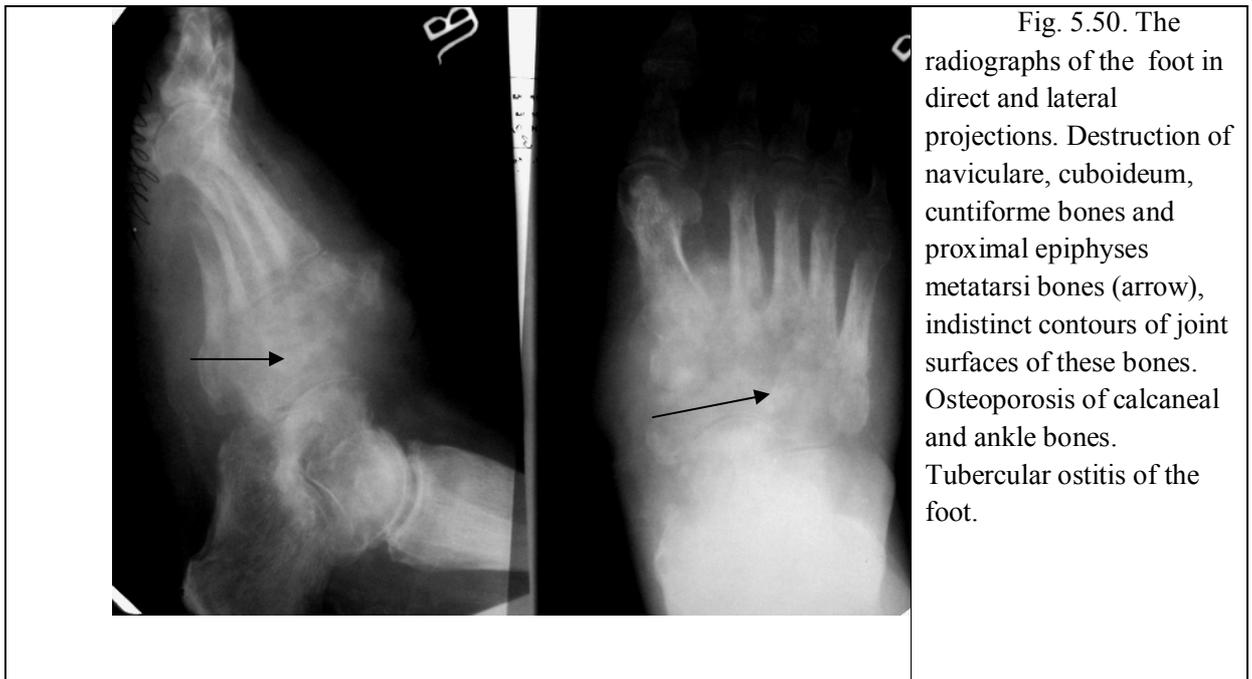


Fig. 5.50. The radiographs of the foot in direct and lateral projections. Destruction of navicular, cuboid, cuneiform bones and proximal epiphyses metatarsi bones (arrow), indistinct contours of joint surfaces of these bones. Osteoporosis of calcaneal and ankle bones. Tubercular osteitis of the foot.

After decrease of inflammations there comes the third phase (postarthritic stage), for which gradual replacement of the inflammatory granuloma by a cicatricial tissue is typical (fig. 5.51).



Fig. 5.51. The radiograph of the knee joint in a direct projection. The image of the joint space on the large extent is absent, subchondral sclerosis, osteophytes (arrow) is detected. Tubercular osteitis in postarthritic stage. Ankylosis of the knee joint.

Localization of the centers is typical for tuberculosis: 1) body of vertebra, 2) flat bones, 3) epiphyses of tubular bones. The centers in epiphyses are frequently large and contain sequestrs from spongiform osteal substance, which are accompanied by roughness of contours of the bone articulate ends and narrowing of the articulate space.

Rheumatoid arthritis. In advanced rheumatoid arthritis severe bone and joint changes are detected and these changes are usually most evident in the hands and feet. The metacarpophalangeal and proximal interphalangeal joints are mainly affected. There is cartilage destruction with loss of joint space, periarticular bone erosion and subluxation of the joints. Severe loss of cartilage with marked osteoporosis will also be seen in other major joints. In the early cases of rheumatoid arthritis bone changes, though less dramatic, may also be quite diagnostic. In the hands there is usually periarticular porosis of bone, and soft-tissue swelling will be evident around the affected interphalangeal joints. Some loss of cartilage may also be seen (fig. 5.52).



Fig. 5.52. Radiographs of hands in a direct projection. Erosion (regional defects) of articulate ends of bones (small white arrows), narrowing of joints (small black arrows), incomplete dislocations and deformation of joints (large white arrows), osteoporosis (black arrows). Rheumatoid arthritis.

Lues affects mainly diaphyses of superficially located bones (tibial, ulnar, clavicles). In lues the centers are small and are situated under the cortex, surrounded by the area of indurated osteal tissue. Here periosteal stratifications merge with the cortical layer (fig. 5.53).

Congenital lues manifests in the first months after the birth.



Fig. 5.53. Radiographs of shins in lateral (a) and a direct projections (b). In bones of shins the signs of osteosclerosis are more evident in tibial bones. Shin bones are thickened and curved (especially the tibia, having bowing deformity). Bones lesion of both shins is detected. The acquired syphilis of shin bones (the tertiary period).

There are two forms of congenital lues: specific osteochondritis and ossifying periostitis. Syphilitic osteochondritis is more common in the large cortical bones of lower extremities.

Three stages osteochondritis are distinguished: the 1st stage – the area of epiphyseal cartilage preliminary calcification extends up to 2-3 sm and becomes more intensive; the 2nd stage - the border of this area from the side of metaphysis acquires rough, serrate contours, transversal light stripy appears under it (Wegner's line); the 3rd stage - the area of preliminary calcification is destroyed irregularly, therefore pathological fractures are possible. In patients the processes of ossification are accelerated. In children syphilitic phalangitis is detected as well; centers of clarification appear inside phalanxes, periosteal stratifications are formed, phalanxes become cylindrically or clavately thickened. Due to disorders in the skull basis ossification the saddle nose is formed.

In patients with acquired lues 2 - 3 years after infection (in the secondary period) the signs of periostites are quite often detected. Sharp changes of bones (gumma) are found out, mainly, in the tertiary period, usually under periosteum and inside a bone to the less extent. In bones small centers or diffuse growths appear. Around the centers there are areas of sclerosis and periosteal stratifications. Bones become thickened also bent, especially tibial bones which acquire acinaciform shape. Process is localized mainly in a bone diaphysis. Multiple symmetric lesions of the skeleton are characteristic. Processes of destruction and osteosclerosis progress simultaneously, but the latter one more often prevails. Sequesters, as a rule, are absent. Joints are seldom damaged. In patients with tertiary lues the destruction of nose osteal septum occurs frequently (saddle nose).

5.8. Radiological sings of bones tumours

The basic method of bone tumours radiodiagnostics is radiography.

The opportunities of radiography in diagnostics of bone tumours:

- majority of initial and metastatic bone tumours is detected, localization is precisely defined;
- detects the type of tumor (osteoclast, osteoblastic, mixed) and growth character (expansive, infiltrative) better than other methods;
- detects pathological fractures.

In diagnostics of malignant bone tumours two situations should be considered.

1) Search for metastases in the skeleton of patients with obviously malignant tumour, especially with a high index of bone tumor dissemination (prostatic, thyroid, mammary gland cancer, lung and nephrocellular cancer), what is important for the choice of treatment mode.

Initial method is bone scintigraphy; it is more sensitive than radiography and allows to visualize the whole skeleton.

As scintigraphy data are nonspecific, the following stage should be radiography of those skeleton parts in which radiopharmaceutical hyperfixation is detected. Positive scintigraphic findings in patients with malignant tumors do not necessarily caused by metastases. Radiography allows to distinguish them better from changes of other nature in the skeleton. In case of retained clinical suspicion in vague radiography data or negative results of scintigraphy CT or MRI should be carried out. According to the published data, in MRI about 80 % of cancer metastases of mammary gland are visualized in the skeleton. Apparently, this advantage of MRI can be used; however it is not unprofitably to use MRI and CT as search method.

2) Clinical suspicion on a neoplasm of this or that part of the skeleton (pain, functions disorder, palpated pathological formation) in a patient. If clinical data indicate multiple skeleton lesions it is better to carry out scintigraphy first. Otherwise radiography can be used. CT or MRI should be used as second-order methods for specification of the nature and the detailed morphological characteristic of a lesion.

Differentiation between initial and metastatic malignant tumours of bones is based on nonspecific radiological signs. For the final decision the biopsy of the bone is performed.

The basic indications for CT in malignant bone tumours:

- In difficulties of differential diagnostics with inflammatory diseases of bones (especially between Ewings sarcoma or malignant lymphoma and osteomyelitis) and in benign tumours. CT quite often gives evidence of malignancy (minimal cortical erosions and extraosseous component of a tumour) or allows to reject it, visualizing, for example, coritical sequester or parossal clump of inflammatory exudation;

- when it is important to visualize mineralized osteal or cartilaginous tumour matrix, especially if mineralization is scanty, CT it is more preferable than MRI, allowing to disinguish osteogenous and cartilaginous tumours.

MRI is the most sensitive and exact method of diagnostics of musculoskeletal system tumours. Advantages:

- detection of initial tumour localization (soft tissues, bone marrow) and its relations to fatty tissue, muscles, bones;

- the most exact estimation of tumour dissemination along the bone marrow (including the "jumping" centers in the same bone); differentiation of a tumour from a perifocal edema demands intravenous injection of contrast agents;

- detection of joint involvement in the process.

MRI is the best method to detect bone tumour stages, it is irreplaceable in planning surgical interventions and radiotherapy. At the same time MRI concedes radiography in differential diagnostics of malignant and benign tumours.

The periodic MRI-control is a deciding condition of well-timed revealing of residual and recurrent tumours after surgical treatment or in radiotherapy and chemotherapy. In contrast to radiography and CT they are distinguished already being small.

Indications for dynamic MRI with contrast agent:

- detection of malignant tumours on the basis of early contrast intensifying in contrast to slowly increasing one in benign tumours (accuracy of 72-80 %); this difference reflects a degree of vascularization and perfusion, not benign or malignant tumour nature: richly vascularized osteoblastoclastoma and osteoblastoma are not distinguishable according to this sign from malignant tumours;
- differentiation of active tumoral tissue from devitalizing one, necrosis and reactive changes what is important for prediction of chemotherapy effect and choice of biopsy site;
- in some cases as addition to native MRI in distinctive recognition of tumoral tissue and postoperative changes, not earlier than 1,5-2 months after operation.

MRI is the most sensitive method of visualization of infiltrative changes of the bone marrow in myelo- and lymph-proliferative diseases (myeloma, lymphoma, leukoses). Diffuse and focal bone marrow changes are frequently found out at a negative X-ray pattern in patients with generalized myeloma.

Primary tumours of bones. Osteosarcoma has characteristic features: destructive process with destruction of all layers of a bone with cortical layer destruction and germination in soft tissues with a calcification of the latter. The osteal structure of a tumour is chaotic, not similar to a picture of the initial bone. Shadows of pathological calcifications are visible: signs "Codman triangle " and " spiculated periosteal reaction". Osteosarcomas favor the metaphysis (fig. 5.54). If sites of destruction are blocked by arising osteal masses sarcoma is called osteoblastic one. If destruction processes prevail in sarcoma it is called osteolytic one. Of Ewing's sarcoma interrupted laminated periosteal reaction is characteristic (5.55). Some sarcomas have a predilection for certain bones. For example, chondrosarcomas favor the pelvis (fig. 5.56).

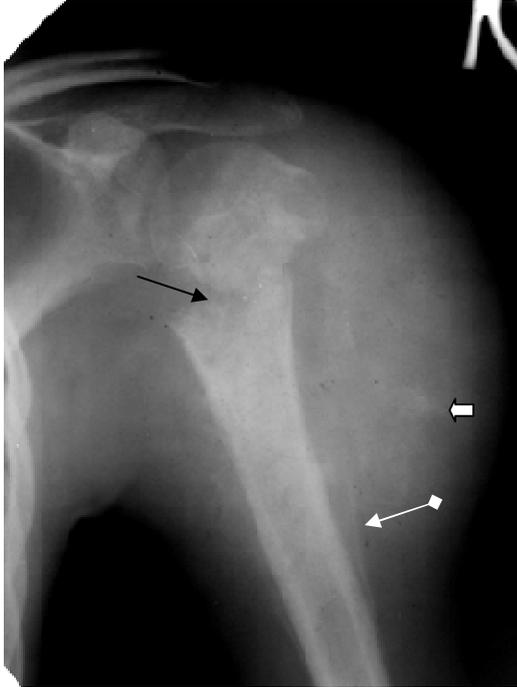


Fig. 5.54. Enlargement radiograph of the humeral joint in a direct projection. In area of proximal epiphysis and humeral bone metaphysis a there is destruction with pathological fracture and cross-section displacement of fragments (arrow). Pathological osteogenesis, extending to the soft tissue, without accurate contours, increase of shoulder soft tissues (a figured arrow). Codman's triangle (arrow with rhombus). Osteosarcoma of the humeral bone with pathological fracture.



Fig. 5.55. Enlargement radiograph of the hip. Destruction of cortical layer of femur diaphysis is detected as well as irregular interrupted laminated periosteal reaction. Ewing's sarcoma of the femur.



Fig. 5.56. Enlargement radiograph of the pelvis in a direct projection. In the area of the iliac bone there is an extensive destruction zone with indistinct contours, involving the cortical layer, pathological bone tissue with non-homogenous structure (arrow). Chondrosarcoma of the left iliac bone is detected.

However secondary malignant bones lesions, i.e. metastases of other organs cancer (MTS) are more common. Of these tumoral lesions presence of malignant process metastasizing in a bone is characteristic. The important feature is multiplicity of MTS. In bones osteolytic form of MTS manifests as multiple centers of destruction with rough contours. As well as in MTS, the centers of destruction can be observed in multiple myeloma. Sternal puncture and some other methods help to differentiate metastases and multiple myeloma (fig. 5.57).



Fig. 5.57. The survey radiograph of the skull in a lateral projection. Multiple sites of destruction of various sizes and round form with distinct contours in bones of the skull (arrow) are defined. Multiple (plasma cell) myeloma is detected.

But under certain conditions there can be osteoblastic MTS. They cause on radiographs is the plural radiopaque sites in a bone with non-legible and rough outlines (fig. 5.58).

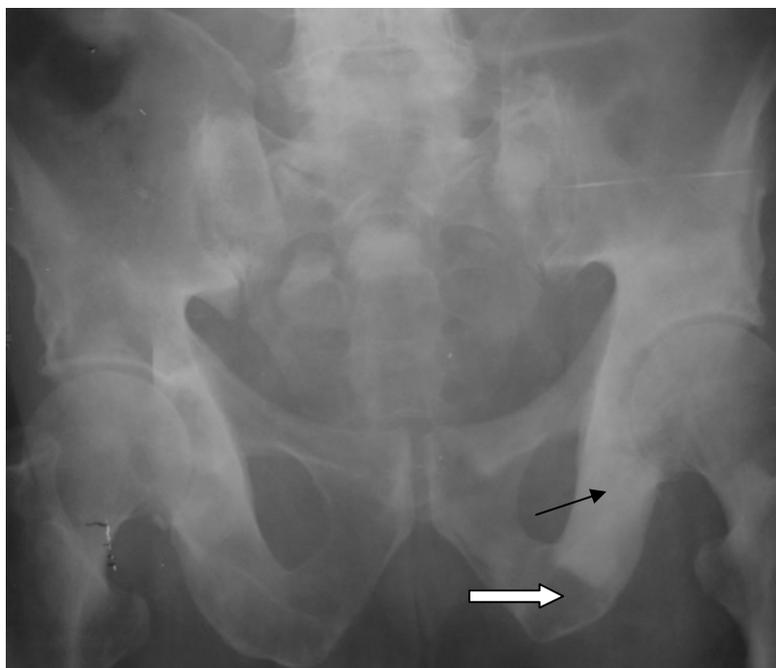


Fig.5.58. The survey radiograph of the pelvis in a direct projection. Multiple sites of osteosclerosis and destruction in pelvic bones are detected. Separate sites of osteosclerosis and destruction are designated by an arrow and a figured arrow, accordingly. Osteolytic and osteoblastic cancer metastases in the iliac bone is detected.

X-ray signs of benign tumours: 1) deformation of a bone; 2) a single shadow of a tumour with distinct contours; 3) absence of periosteal reactions; 4) cortical layer is not interrupted; 5) osteal structure of a tumour is changed, but keeps the common features of a maternal, initial bone; 6) there are no calcifications of surrounding soft tissues (fig. 5.59).



Fig. 5.59. The radiograph of the humeral bone in a direct projection. The mass in the top third of diaphysis of the humeral bone with wide basis connected with the bone is detected. There are no periosteal reactions, contours are distinct. Radiological symptoms of osteoma are detected (a benign tumour of a bone).

Benign tumours can contain calcification centers (chondroma, osteochondroma) (fig. 5.60, 5.61).



Fig. 5.60. The radiograph of the ulnar joint in direct and lateral projections. The pathological mass, which surrounds the ulnar joint (arrows) is detected. There are lucent sites and zones of calcifications with various sizes and forms; contours are distinct, but not along the whole length. Ecchondroma of ulnar joint bones.



Fig. 5.61. Enlargement radiograph of the hip in a lateral projection. In area of femur distal metaphysis the mass is detected along the back surface; the mass has the basis in the form of a crus and wider peripheral part. Its structure is non-homogeneous in peripheral parts, contours are rough, distinct (arrow). Bone cortical layer crosses a tumour surface. Osteochondroma of the femur in the area of distal metaphysis is detected.

The can give absolutely unstructured defect (fig. 5.62). Slow growth of tumor is characteristic in view of the general good condition of patient.



Fig. 5.62. Enlargement radiograph of the hip in a direct projection. The site of destruction with smooth and accurate contours in proximal femur (arrow) is detected. External bone cortical layer in this zone is thin. Femur cyst is detected.

In differentiation of inflammatory process and a tumour it is necessary to consider that, destruction can be present in primary tumour as well as in inflammatory process, but in tumour: 1) sequestrs, 2) laminated solid periosteal reaction, 3) transition to a joint are absent. If a lesion has crossed the joint space, most likely it is the inflammatory process. Besides longitudinal diffusion is typical for osteomyelitis; transversal direction – for a tumour.

5.9. Radiology sings of degenerate - dystrophic joints diseases

The most often diseases of joints are degenerate – dystrophic ones, occurring from different and not always clear reasons (traumas, overloads, protein exchange disorders, etc.). The main radiological signs: 1) narrowing of the X-ray articulate space; 2) osteal growths along the edges of articulate surfaces (spur formation); 3) deformation of articulate surfaces; 4) sclerosis of subcartilage layers of the osteal tissue in both articulate ends, especially in their most loaded sites; 5) cystoid formations giving clarification in the articulate ends of bones. In contrast to the destructive centers, they have correct form, distinct smooth contours and do not contain sequestrs (fig. 5.63).

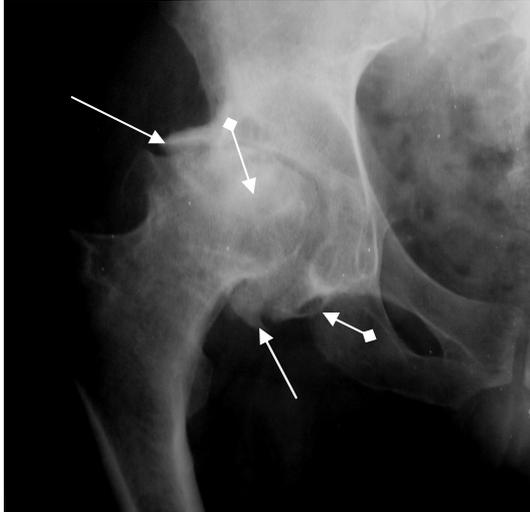


Fig 5.63. Enlargement radiograph of the right hip joint in a direct projection. Narrowing and deformation of joint, osteophytes (arrows), subchondral sclerosis, degenerative synovial cysts are detected in both femoral head and acetabulum (arrows with rhombus) is indicated. Osteoarthritis of the hip joint is detected.

In ultrasonic scanning regional osteophytes, ossificates and even degenerative subchondral cysts are detected, as well as severe changes of the articulate cartilage down to its defects, especially in large superficial joints (knee joint).

Necessity in MRI seldom arises. False-positive results are common in estimation of degenerative changes of articulate cartilages in the early stage of a lesion.

CHAPTER 6. PULMONARY IMAGING

6.1 X-ray methods of respiratory system examination

Chest radiograph is the primary and the most frequent method of lung examination. In addition, it is the examination that you most likely will review by yourself. Chest radiographs number more than half of all the examinations performed in any radiology practice. Chest radiograph certainly is used to diagnose pulmonary diseases, traumas of thorax and polytraumas, in patients with not clear reasons of fever, in patients with oncological diseases.

Chest radiograph can be of 2 types: survey and targeted. Survey chest radiograph (fig.6.1, 6.2), as a rule, are carried out in two projections - direct and lateral (how the body is oriented to the x-ray source).

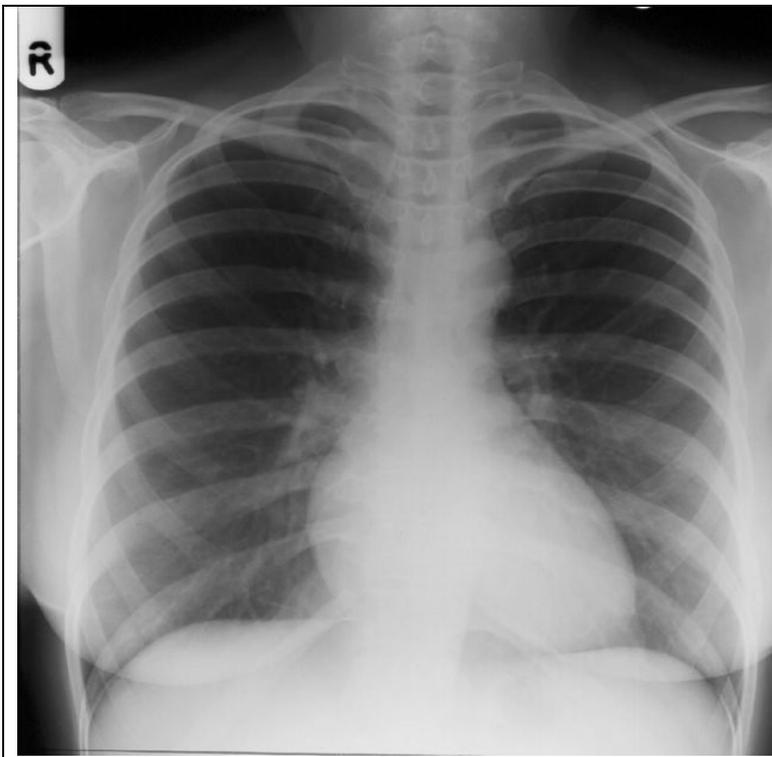


Fig. 6.1. Chest radiograph. Posterior-anterior projection.
Norm.

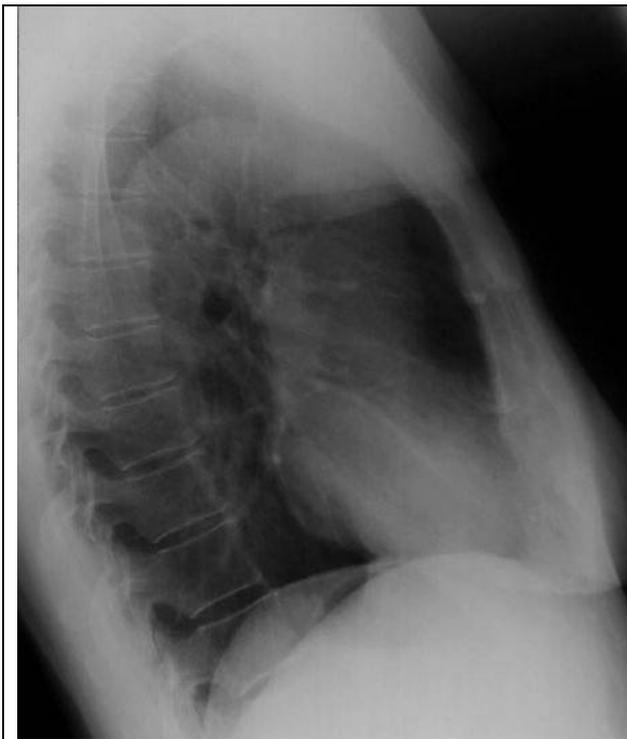


Fig 6.2. Chest radiograph, right lateral projection
Normal view.

Tomography. The technique is the following stage in radiological examination. The longitudinal (conventional) direct tomography is carried out more often. The median cut is made at the level of half of thorax's width; the middle of anteroposterior diameter (from the back to the sternum) in the adult is 9-12 cm. The anterior cut is 2 cm closer from the median one anteriorly; the posterior cut is 2 cm retraced from the median one. Shadows of neither anterior nor posterior parts of ribs are not detected on the median tomogram. Anterior parts of ribs can be seen on the anterior tomogram, posterior parts, vice versa, can be visualized on the posterior tomogram. (fig. 6.3). Usually according to these basic attributes topographical lung cuts can be easily identified. The longitudinal tomography is applied for:

- estimations of major airways;
- specifications of structure of pathological formation (disintegration, calcification);
- tumour detection against the background of obstructive changes;
- visualization of the increased lymph nodes in lungs and mediastinum.

CT. The computed tomography provides the diagnostic information unattainable by other methods (fig. 6.4). CT it is applied for:

- detection of the pathological changes hidden by pleural exudate;

- assessment of microfocal disseminations and diffusive interstitial pulmonary lesions;
- differentiation of solid and liquid formations in lungs;



Fig. 6.3. Convencional tomography of a chest in a direct projection at a level of a bifurcation of a trachea.

The right upper lobe gives an intensive shadow and diminished in sizes.

Atelectasis upper lobe of right lung.

- detection of focal lesions up to 15 mm;
- detection of larger foci of lesion located inconveniently for diagnostics or with insignificant increase in density;
- visualization of pathological formations in mediastinum;
- estimations of intrachest lymph nodes. At CT lymph nodes of lung roots can be seen since they are 10 mm (at CT - not less than 20 mm). Being smaller than 1 cm they are regarded as normal; from 1 up to 1,5 cm - as suspicious; the bigger ones are considered to be definitely pathological;
- solutions of the same questions as at a convencional tomography as well as when the lattest is non-informative;
- in case of probable surgical or radiotherapy treatment;

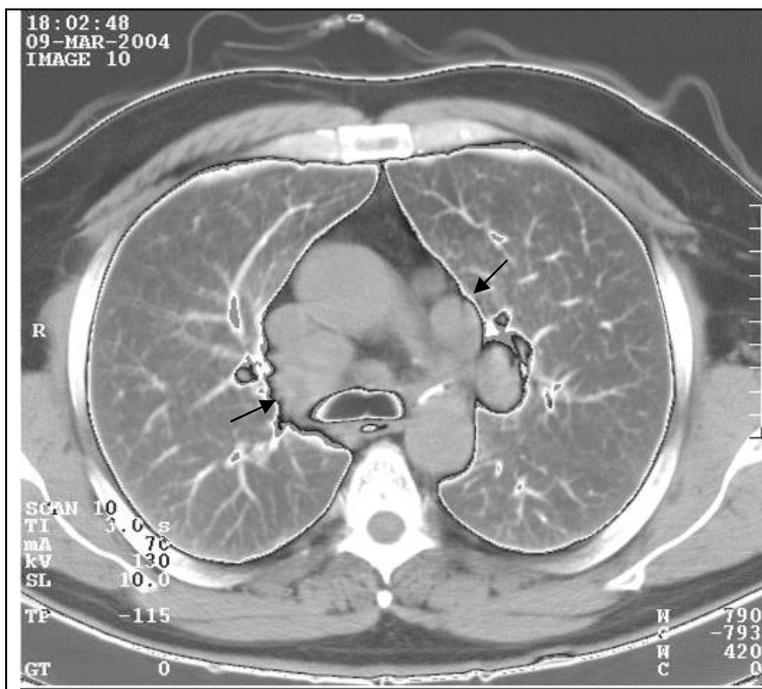


Fig. 6.4. CT-scan at a level of a bifurcation of a trachea. Enlarged lymph nodes without a calcification in a mediastinum (arrows). Hodgkin's lymphoma.

Roentgenoscopy. Its advantage is in reception of the image in real-time mode, in estimation of movement of thoracic structures, in multiaxial examination which provides with adequate spatial orientation and with the choice of optimal views for target images. Besides punctures and other manipulations on thoracic organs are carried out under the control of roentgenoscopy.

Fluorography. Fluorography, as a screening method of lung visualization, is supplemented with full roentgenography in difficult cases, at absence of positive dynamics within 10-14 days or in all cases with pathological changes and with negative results differing from clinical picture. Children are not exposed to fluorography because of higher radiation dose, if compared to roentgenography.

Bronchography. The method of contrast examination of bronchial tree is called bronchography. Often lipiodol serves as a contrast medium for bronchography.

Introduction of contrast medium into tracheobronchial tree can be performed in different ways. The most wide-spread methods are those with the use of catheters: transnasal catheterization of bronchi under local anesthesia and bronchography under narcosis. After introduction of contrast medium into tracheobronchial tree serial images are made regarding the sequence of bronchial system contrasting.

As a result of the development of bronchoscopy, which is based on fiber optic, diagnostic value of bronchography has decreased. It is used now mostly when bronchoscopy does not give satisfactory results.

Angiopneumography is a technique of contrast examination of vessels of lesser circulation. Selective angiopneumography is used more often. It involves introduction of radiopaque catheter into the cubital vein with its subsequent conducting through the right cardiac cavities either to the left or to the right trunk of pulmonary artery. The following step of examination is to introduce 15-20 ml of 70% water solution of contrast medium under pressure and making serial images. The following diseases of pulmonary vessels can be indications for this method: embolism, arteriovenous aneurysms, pulmonary varices, etc.

6.2. Radionuclide examinations of respiratory apparatus

Radionuclide diagnostics methods are directed at investigation of three main physiological processes which are the basis for external breath: alveolar ventilation, alveolar-capillary diffusion and capillary blood flow (perfusion) of the pulmonary arterial system. Nowadays applied medicine does not have more informative methods of registration of regional blood flow and pulmonary ventilation.

Two kinds of radiopharmaceuticals are usually used for such investigations: radioactive gases and radioactive particles.

Regional ventilation. Radioactive gas ^{133}Xe ($T_{1/2}$ biol. - 1 min., $T_{1/2}$ phys. – 5.27 days. γ -, β - rays). Investigation of alveolar ventilation and a capillary blood flow with ^{133}Xe is carried out on the multidetector scintillation devices or the gamma camera.

Radiopulmonography (radionuclide ventilation study)

Introduced intratracheally ^{133}Xe (xenon) is distributed to various lung parts according to the level of ventilation of these zones (fig.6.5). Pathological processes in lungs, resulting in local or diffusive disorders of ventilation, reduce gas amount getting into affected parts. It is registered with the help of the radiodiagnostic facilities. External registration of xenon γ -radiation enables to obtain graphic record of ventilation and blood-flow levels in any part of the lung.

Intrapulmonary dynamics of ^{133}Xe depend on the extent of alveolar participation in external respiration and on permeability of alveolar-capillary membrane.

Perfusion scintigraphy of lungs. It is applied for examination of pulmonary blood flow, mainly for diagnostics of pulmonary thromboembolism. Radiopharmaceutical $^{99\text{m}}\text{Tc}$ (technetium) is used which is the macroaggregate of human serum albumin. The principle of a method is in time blockade of an insignificant part of pulmonary capillaries. In some hours after an injection albuminous particles are destroyed by blood enzymes and macrophages. Disturbance

of a capillary blood flow are accompanied by change of normal accumulation of radiopharmaceuticals in lungs (fig.6.6).

PET (positron emission tomography) is the best way to detect lung cancer expansion. Examination is carried out with the radiopharmaceutical 18-fluorineglucose. Application of a method is limited by its high cost (fig.6.7).

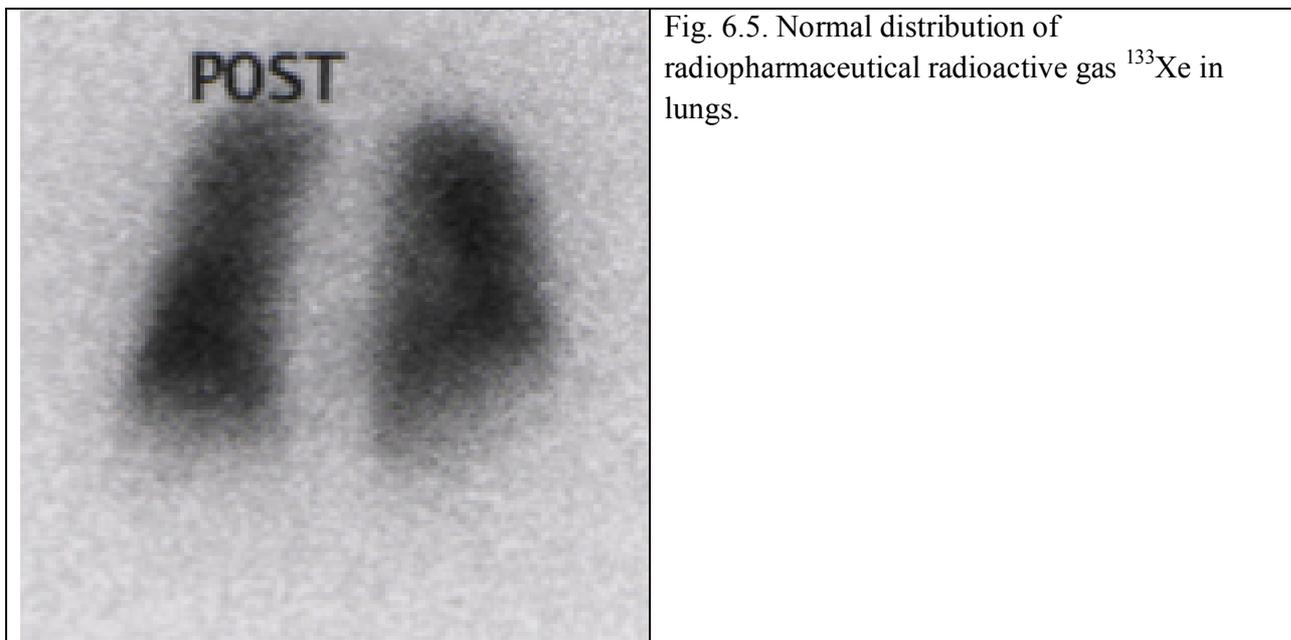


Fig. 6.5. Normal distribution of radiopharmaceutical radioactive gas ^{133}Xe in lungs.

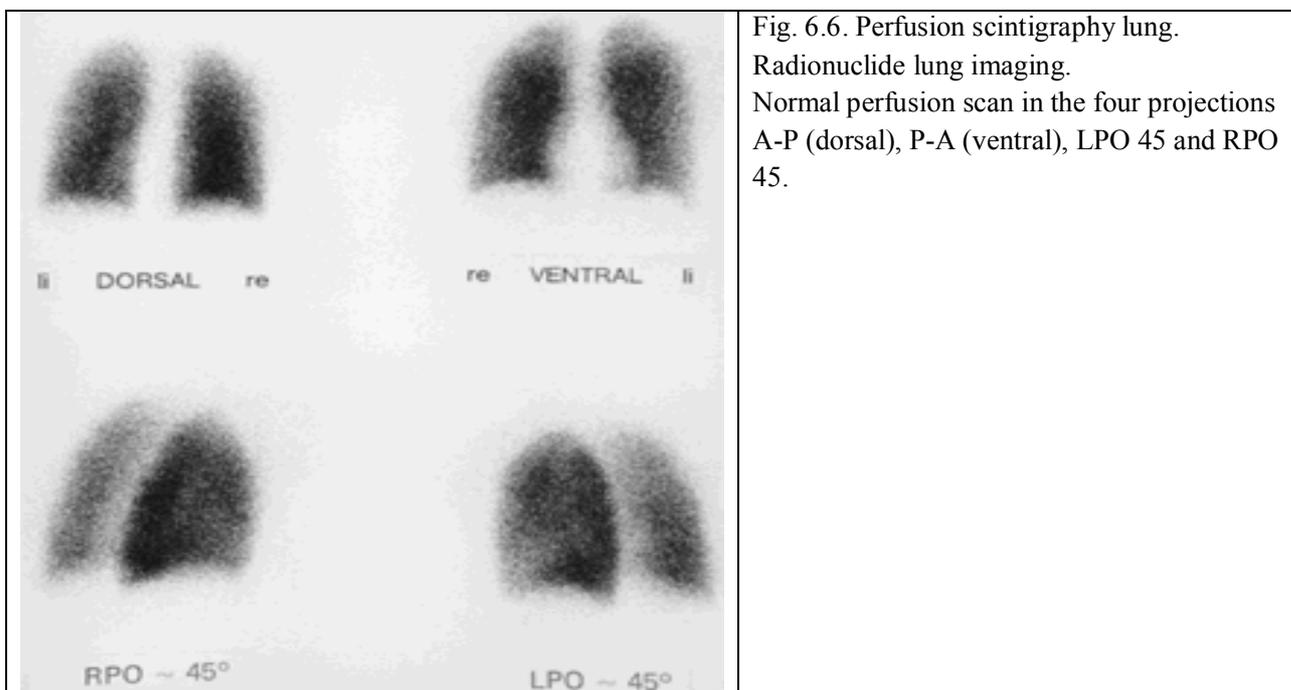


Fig. 6.6. Perfusion scintigraphy lung. Radionuclide lung imaging. Normal perfusion scan in the four projections A-P (dorsal), P-A (ventral), LPO 45 and RPO 45.

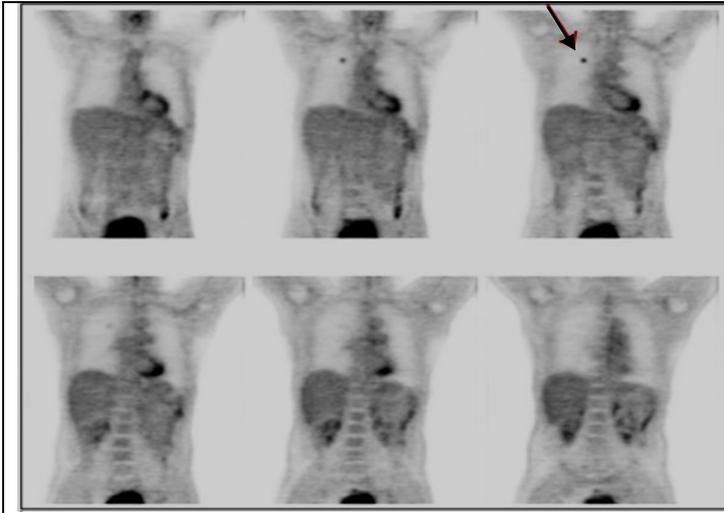


Fig. 6.7. PET: small cancer of lung (arrow).

6.3. Role of MRI in diagnostics of diseases of organs of breath

Application of MRI is limited, mainly, to visualization of pathological formations mediastinum and roots lung, defects of a chest wall, soft tissues revealing and the characteristic of diseases of large vessels of a chest cavity, especially aortas. Clinical value MPT pulmonary parenchyma is insignificant (fig.6.8).

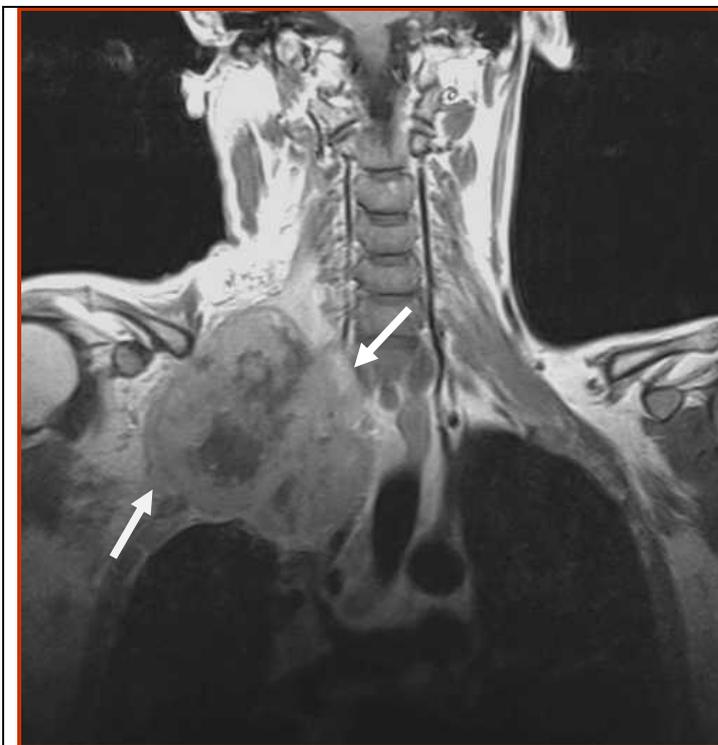


Fig. 6.8. Coronal T2-weighted MRI a thorax. A tumor (cancer) of a top of the right lung, sprouting in soft tissues and a backbone (arrows).

6.4. Role of ultrasonic in diagnostics of respiratory system diseases

This method has the limited value in diagnostics of the majority of diseases of thoracic organs (except for diseases of cardiovascular system). It enables to receive the information concerning the formations adjoining the thorax, pleural cavity (liquid and dense formations) and a diaphragm (about movement and the form); also information about the formations which are developing in certain departments of mediastinum (for example, thymus gland).

6.5. The analysis of the chest radiograph

For a systematic evaluation, a chest radiograph should first be looked at from a technical viewpoint. Rotation: assess the distance from the medial ends of the clavicles and anterior ends of the ribs to the centre of the vertebral bodies, which should be equidistant.

Inspiration: adequate inspiration is identified by the appearance of six anterior ribs above the hemidiaphragm, whereas eight or more visible ribs suggest hyperinflation. Four ribs or fewer are seen in hypoaeration. The anterior ribs are more reliable in children as the dome of the diaphragm is anterior. Penetration: intervertebral disc spaces should be visible through the cardiac shadow, and central pulmonary vessels also easily seen, in the presence of adequate penetration. Outlines of structures should be well-defined. There should be a systematic approach to examination of the findings on a chest radiograph, to ensure that possible pathology is not overlooked. The ribs of the radiograph are inspected. This includes the abdomen, neck and shoulders. The position of any tubes or catheters is noted. The shape of the thorax is inspected, and checked for symmetry. The soft tissues of the chest wall and the bony thorax are evaluated. The contours of the hemidiaphragms, mediastinum, heart and pleura are inspected.

Then the structures within the mediastinum are assessed individually: the trachea and major bronchi, the great vessels, the thymus and the locations of lymph nodes. The size of the heart and pulmonary vessels is evaluated, and the contribution to the cardiac contour by individual chambers is assessed. The spine and paraspinal structures are probably best evaluated at this time also.

The pulmonary parenchyma is then surveyed, paying particular attention to areas obscured by other structures, that is, the retrocardiac region, the lung apices, and below the dome of the diaphragm.

The analysis of direct chest radiograph should start with an estimation of technical qualities of a picture. The radiograph should capture a thorax completely from apex to diaphragm and costodiaphragmatic recesses. Symmetric position of sternal ends of the clavicle towards the edges of the thoracic vertebral bodies (spinous processes) indicates that the position of a patient's body during the radiography is correct.

If specifications are set correctly (current, voltage, exposure), three or four bodies of top vertebrae can be seen on the radiograph; other chest vertebrae are outlined only slightly as a continuous shadow on mediastinum.

The radiograph should be contrast enough: a median shadow and liver region should be white; and lung fields should be dark, with the distinct image of lung pattern. Outlines of a diaphragm, top edges of ribs, heart should be distinct. After an estimation of technical qualities of a picture, one should proceed with the radioanatomical estimation of a thorax.

First of all, the right side of a thorax should be differentiated from the left one. You should pay attention to a heart's shadow: in a healthy person 1/3 of this shadow is situated to the right of the midline; and 2/3 to the left.

The diaphragm limits lung fields by dome-shaped shadow from below. In the central part it is situated in the highest position, and closer to the bottom it forms external costodiaphragmatic recesses. The diaphragm is mostly situated in the sixth rib (front department). The rib "crosses" a diaphragm in the center. The right slope of a diaphragm is 1-1,5 cm above than left one.

Some muscles and soft tissues of chest wall are projected onto lung fields. It should be taken into account that decrease in transparency of pulmonary fields can be caused by stratification of sternocleidomastoid, big and small pectoral muscles, wide muscles of a back, mammary gland and mammae.

On the direct radiograph such bone elements as ribs and clavicle are visible. Ribs are projected against the background of transparent pulmonary fields as 9-10 pairs from both sides. Posterior and anterior fragments of ribs should be differentiated. Posterior fragments form more intensive shadows and have a short curve upwards near vertebrae, and then they are directed downwards and ectad. Anterior fragments are lower than the posterior ones corresponding to them, and are directed from and above to the inside and downwards; the forward ends of ribs pass into costal cartilages which do not produce a shadow on radiographs of children and young people.

Shadows of lung roots (hilum or hilar zone) are also various. Lung roots on radiographs present an image of big arterial and venous vessels, partially of bronchi.

The root of left lung is hidden behind the image of heart, but its top border is always distinctly marked by a wide shadow of the left branch of pulmonary artery. The root of right lung, as a rule, has no such distinct top border. Lung roots on radiographs present an image of right and left pulmonary arteries with all their branchings. Lymph nodes and walls of large bronchial tubes are not part of the shadow image of a lung root. Lung roots form the oblique shadows on each side of mediastinum which remind of a configuration of a comma or a half moon. On the right the shadow of a root is separated from a median shadow by a transparent strip (≈ 1 cm), representing a projection of the basic and right lower-lobe bronchial tube; on the left the root is usually hidden by shadow from heart. The location of the top border of lung roots is defined by a level of the largest vascular trunks (intercostal level II). The top border of the left root is located above. The width of a root in the adult varies from 1,5 up to 2,5 cm, and the left root is always wider than the right one.

The external contour of a shadow of a root is rectilinear or slightly concave. Camber or polycyclicity of a contour of a root testifies its pathology. Right root is subdivided into head, body and tail. The head is situated on the level of cartilaginous parts of the 2nd rib; the body is between the 2nd and the 3rd ribs, and a tail part extends from the 3rd rib downwards to the 4th rib. Lung roots should be studied with the help of the shadow picture obtained at height of a deep breath and preferably in the vertical position of the patient. The root is normally structured, i.e. its shadow is non-homogeneous because of its projective stratification of vascular branches on the pulmonary artery, as well as of bronchial cross-section.

In small children lung root regions are hidden by heart shadow more than in older children and adults. Roots of lungs are shaded by cross-sectioned heart and wide thymus. The median shadow represents mediastinum, backbone and sternum. However, during examination of the patient in a direct projection the median shadow, first of all, is a cardiovascular shadow since other formations are not represented outside cardiovascular bunch. Lymph nodes can be found in mediastinum as well as in lung roots. Because of small size they cannot be seen on images. But at the same time the radiological method is the leading one in detection of pathologically changed intrachest lymph nodes.

Against the background of transparent pulmonary fields shadows can be seen that are images of pulmonary blood vessels - arteries and veins. Bronchi and connective tissue interlayers normally are not visible. Elements of pulmonary image (pulmonary blood

vessels) are extended through 3/4 pulmonary fields, in external departments they are not visible. Shadows of vessels are bigger and more intensive in medial areas. Along certain linear shadows and at their ends small roundish or oval dense shadows are visible. Their diameter usually corresponds to the width of those linear shadows of lung pattern which are stratified or which they end with. Closer to the root they are the biggest. Roundish or oval shadows are image of axial or oblique blood vessel section, unlike longitudinal projection at linear imaging.

In the upper part of a thorax the right outline of a median shadow goes along a right edge of spine shadow, but the arched bottom protrudes in the right pulmonary field, situated 1-2,5 cm ectad the right edge of spine shadow. As to the left outline of a median shadow, it protrudes considerably further to the left of edge of spine shadow. Its the most left point is 1,5-2 cm inward from left medclavicular line.

Lobes of the right lung are projected on the anterior chest wall as follows: the upper lobe occupies space from the apex to the anterior part of the 4th rib, the middle lobe - from the 4th rib to the 6th one, the lower lobe - from posterior part of the 4th-5th ribs to the diaphragm. On the left the upper lobe is extended from the apex to the anterior part of the 6th rib, the lower part - from posterior part of the 3rd-4th ribs to the diaphragm.

Lateral viewing can simplify the localization of pathological processes in lungs. First, on the lateral image the peak of the diaphragmatic cupula should be found. A straight line is drawn from it through the shadow of the middle of the root till its crossing with the spine. This line corresponds to an oblique fissure and separates the lower lobe from the upper one in left lung, and from the upper and the middle in right lung (fig. 6.9).

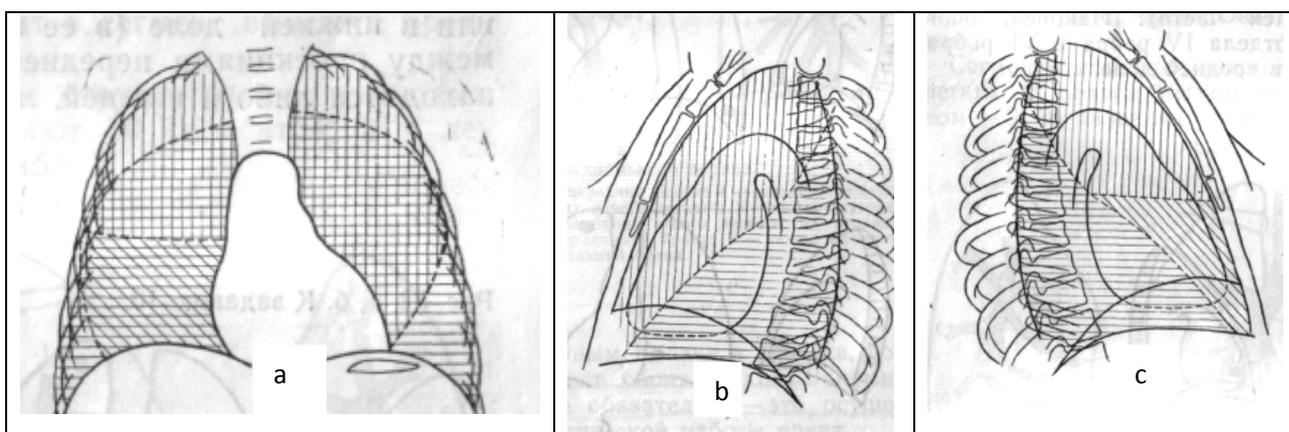


Fig. 6.9. Projection of lung lobes in a posterior-anterior (a), left lateral (b) and right lateral views(c). Vertical shading marks the upper lobe, the oblique shading– middle lobe, the horizontal shading–

the lower lobe.

Additionally drawing a horizontal line from the middle of the root towards thorax will mark location of the interlobe fissure dividing the upper and middle lobe. Trachea divides into two main bronchi: the right and the left. They are considered to be mainstem bronchi. The main bronchi divide into lobar bronchi, i.e. bronchi of the second order (there is also an intermediate bronchus on the right). Lobar bronchi divide into tertiary bronchi also known as segmental bronchi. Each segment also has an independent segmentary artery besides bronchus. The artery enters the segment with the bronchus. The upper lung lobe consists of three segments: 1 apical, 2 posterior, 3 anterior.

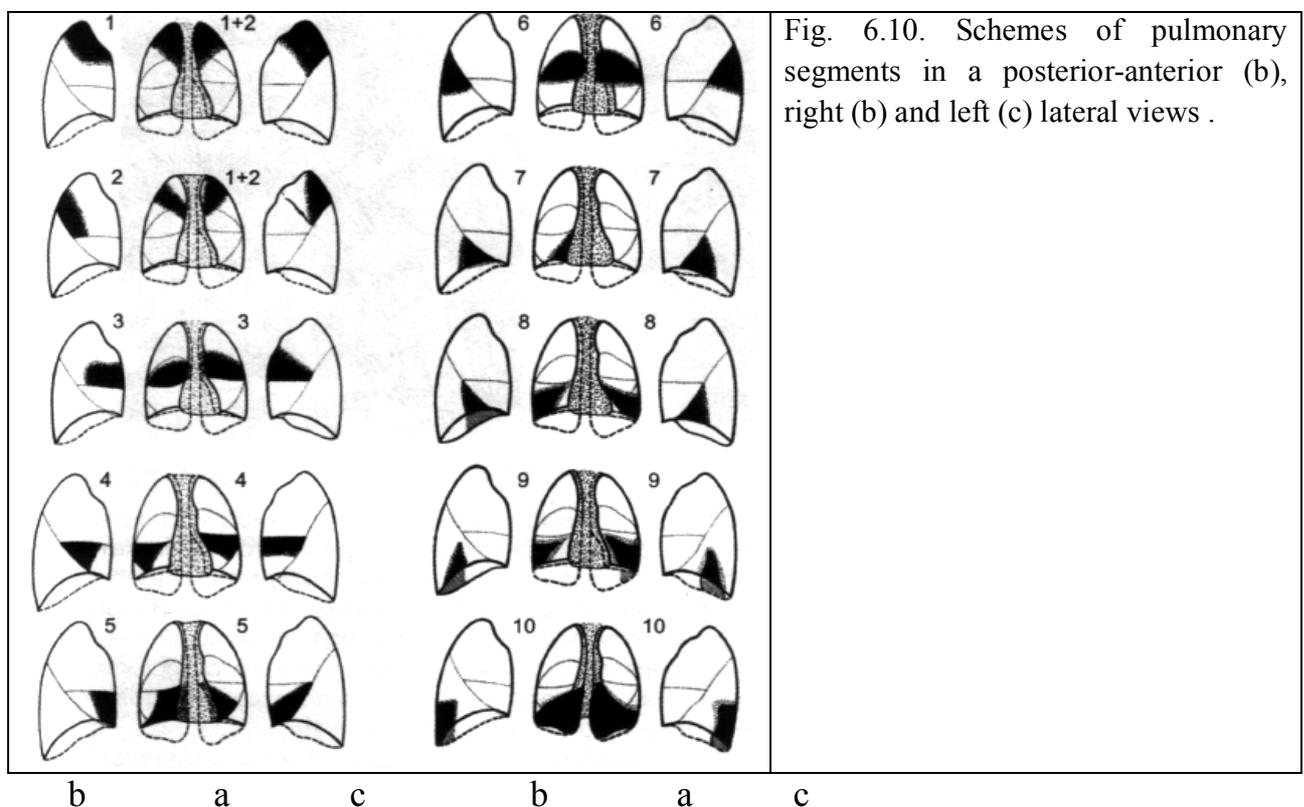


Fig. 6.10. Schemes of pulmonary segments in a posterior-anterior (b), right (b) and left (c) lateral views .

The middle lobe consists of two segments (4-5). Right lung: 4 - external, 5 - internal segments. Left lung: 4 segment - upper uvular and 5 segment - lower uvular. The lowest lobe lung on the right will consist of 5 segments: 6 - superior, 7 - medial basal, 8 - anterior basal, 9 - lateral basal, 10 - posterior basal. In left lung only 9 segments allocate quite often, 7 is absent (fig. 6.10).

6.6. The main radiological syndromes at lung injuries and diseases.

There are nine basic syndromes of radiological symptoms of lung pathology:

1. Total or subtotal shadowing of pulmonary fields.

2. Limited shadowing of pulmonary fields.
3. A round shadow in pulmonary field.
4. Limited radiolucency.
5. Foci and limited dissemination.
6. Diffusive disseminations.
7. Pathology of pulmonary image.
8. Pathology of a lung root and of bronchial lymph nodes.
9. Extensive radiolucency of pulmonary field.

To characterize each shadow on the image completely, it is necessary to know the following eight attributes of a shadow:

1. Location of a shadow.
2. Number of shadows.
3. Form of a shadow.
4. Sizes of a shadow.
5. Intensity of a shadow.
6. Figure of a shadow (structure).
7. Contours of a shadow.
8. Ability of a shadow to shift.

First seven attributes are estimated according to radiographs, and the eighth one (ability to shift) mainly at fluoroscopy.

Numerous pathological processes in lungs cause changes in their transparency.

Total or subtotal shadowing of pulmonary fields. X-ray imaging reveals the symptom of shadowing in case of infiltration of pulmonary tissues, increasing of a tumour node fluid accumulation, airless parts of lung. A total or subtotal shadow is formed due to atelectasis, pneumonia of all lung, total exudative pleurisy, cirrhosis of lung, diaphragmatic hernia. If mediastinum is shifted opposite to shadow, it indicates a pathological process in a pleural cavity (fig.6.11.).



Fig. 6.11. The anteroposterior chest radiograph reveals a large right pleural effusion extending around the lung laterally towards the apex. Notice, the mediastinum is shifted to the left.

If the shadow is homogeneous, then the patient has accumulation of fluid in lungs. If it is non-homogeneous, then the patient has diaphragmatic a hernia (fig. 6.12).

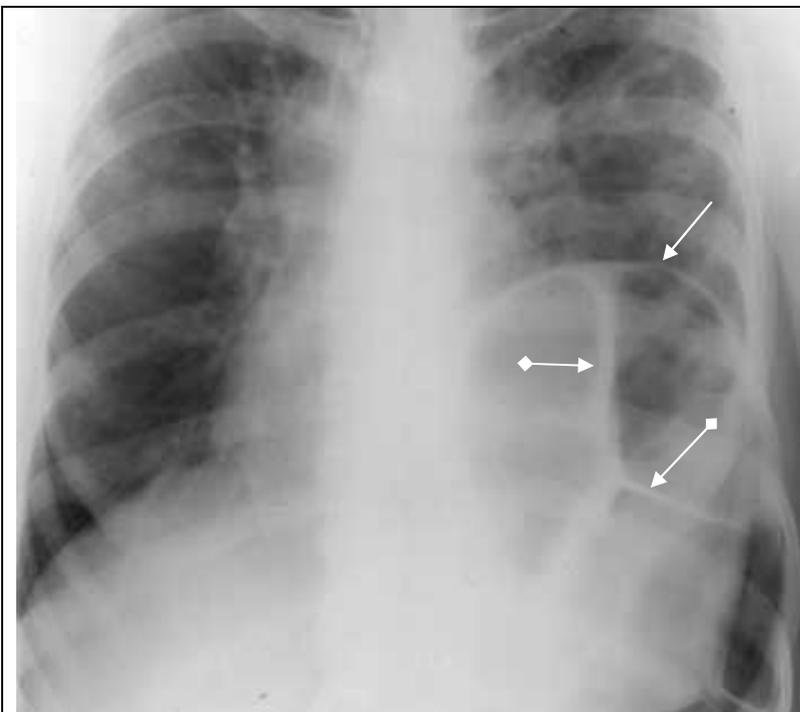


Fig. 6.12. The anteroposterior chest radiograph. In the left pulmonary field a subtotal non-homogenous shadow with the radiolucent zone (white arrow) divided by linear shadows (arrows with rhombs). Pulmonary vasculature in the left lung is prominent. Mediastinum is shifted to the right. The cupula of diaphragm on the left is not differentiated clearly. Diaphragmatic hernia at the left.

When mediastinum shifts aside, pneumosclerosis, atelectasis, condition after pneumonectomy are possible (fig. 6.13).

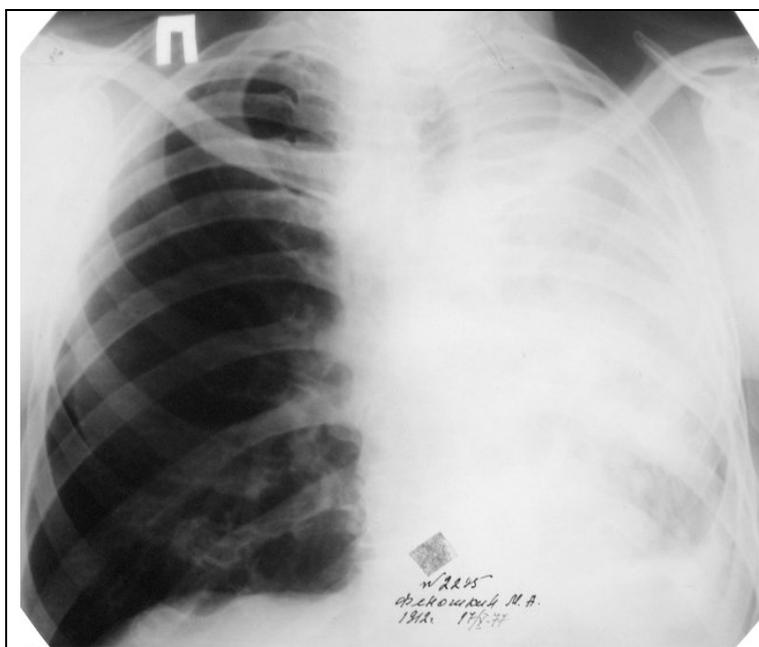


Fig. 6.13. Total shadow in the left pulmonary field. Post-anterior chest radiograph of a patient with obstructive atelectasis of the left lung due to central bronchogenic carcinoma.

At atelectasis shadow is homogeneous, and at pneumosclerosis it is not. (fig. 6.14).

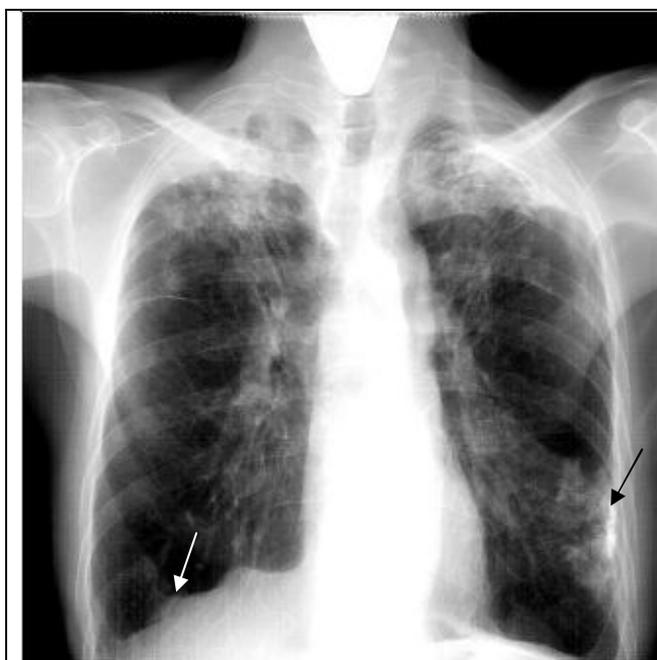


Fig. 6.14. The frontal chest radiograph. Extensive non-homogeneous intensive shadow in both pulmonary fields, mainly in the upper parts, due to numerous foci, fibrosis and pleural layers. Lung roots are shifted up. On the left at the level of the anterior departments of the VI-VIII there is intensive, non-uniform calcined shadowing (black arrow). On the right the diaphragmatic cupula is deformed by pleuro-diaphragmatic commissures (white arrow). Right dome of the diaphragm is deformed pleurodiaphragmalnyimi adhesions (white arrow). Cirrhotic tuberculosis of both lungs. Calcification of the pleura on the left

At pneumonia mediastinum is not shifted (fig. 6.15).

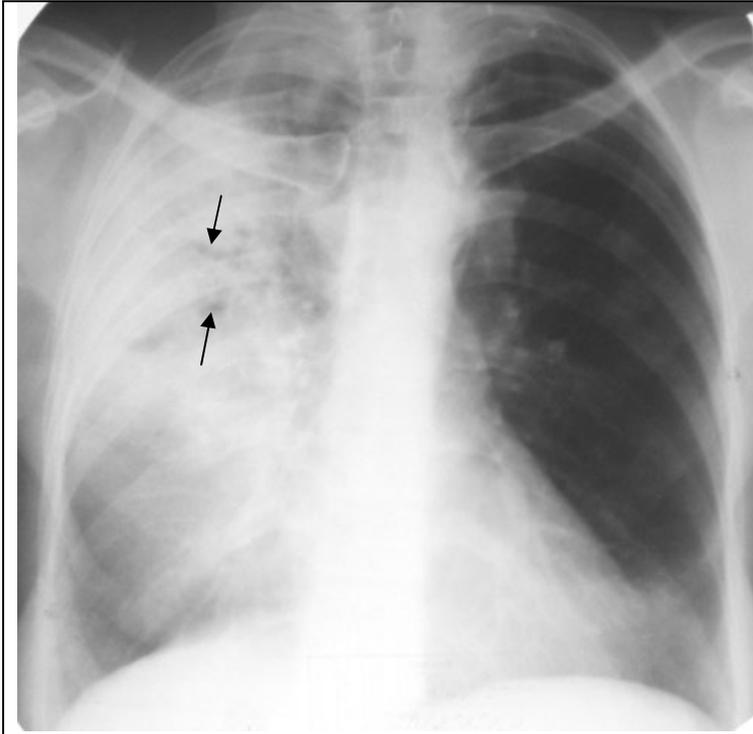


Fig. 6.15. Total shadowing of right pulmonary field, air bronchogram (arrows). Acute pneumonia of the lower lobe of the right lung.

Fluid accumulation can be easily identified with the help of US and CT.

The limited shadowing in lung detects involvement of a lung lobe, of one or several segments, exudativ and encysted pleurisy, diaphragmatic hernia, mediastinal tumours (fig. 6.16, 6.17).

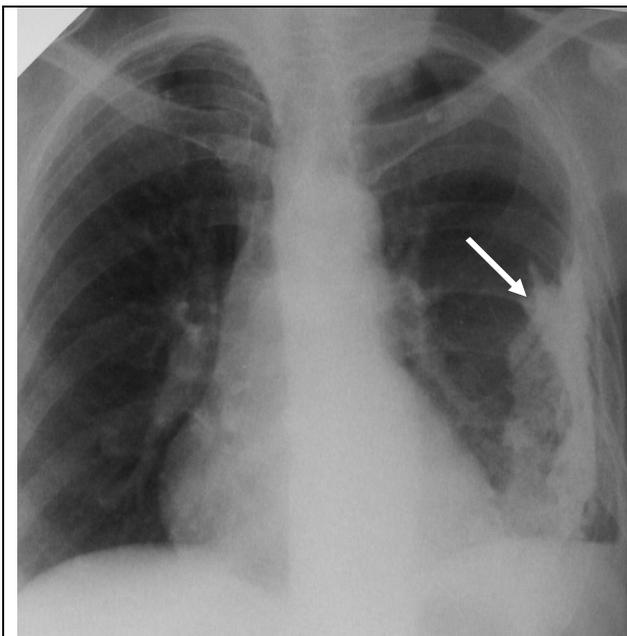


Fig. 6.16. The frontal chest radiograph. There is an intensive limited shadow with accurate rough contours in the left pulmonary field. The shadow is more intensive in the lateral department (arrow). Calcification pleurae on the left.

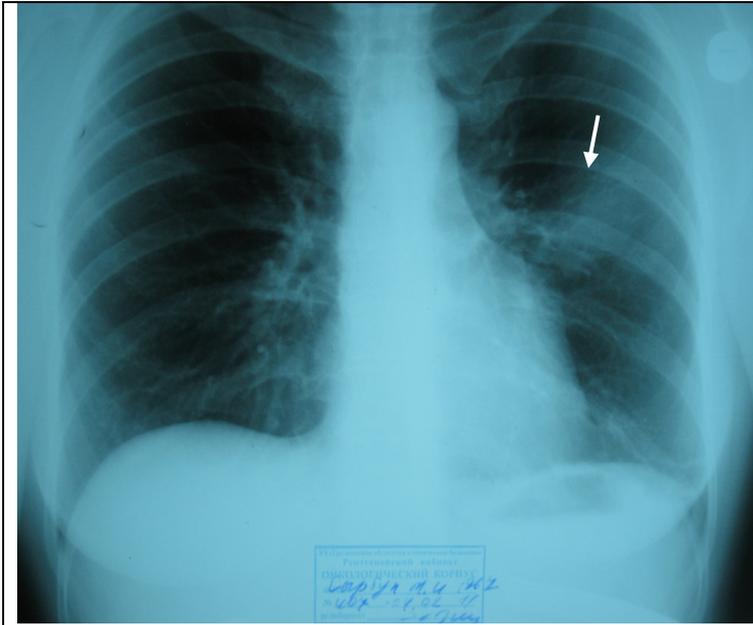


Fig. 6.17. Chest radiograph. In the middle zone of the left lung there is a limited shadow of average intensity with not distinct contours (arrow). Acute pneumonia in the third segment of left upper lobe.

Nodular shadows can be: small with size up to 0.3 cm in diameter; average (0.3 – 0.5 cm), large (0.5 - 1 cm in diameter). Pulmonary focus is a result of acinus affection (small foci - miliary) or lobules (large foci). Frequently nodular shadows are numerous (acute pneumonia, hematogenic disseminated tuberculosis, pneumoconiosis, tumor deposits, etc., fig. 6.18).

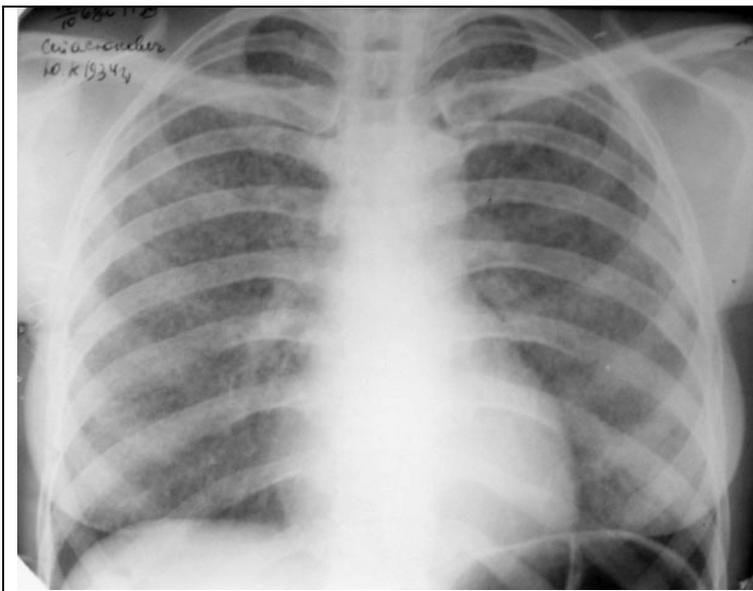
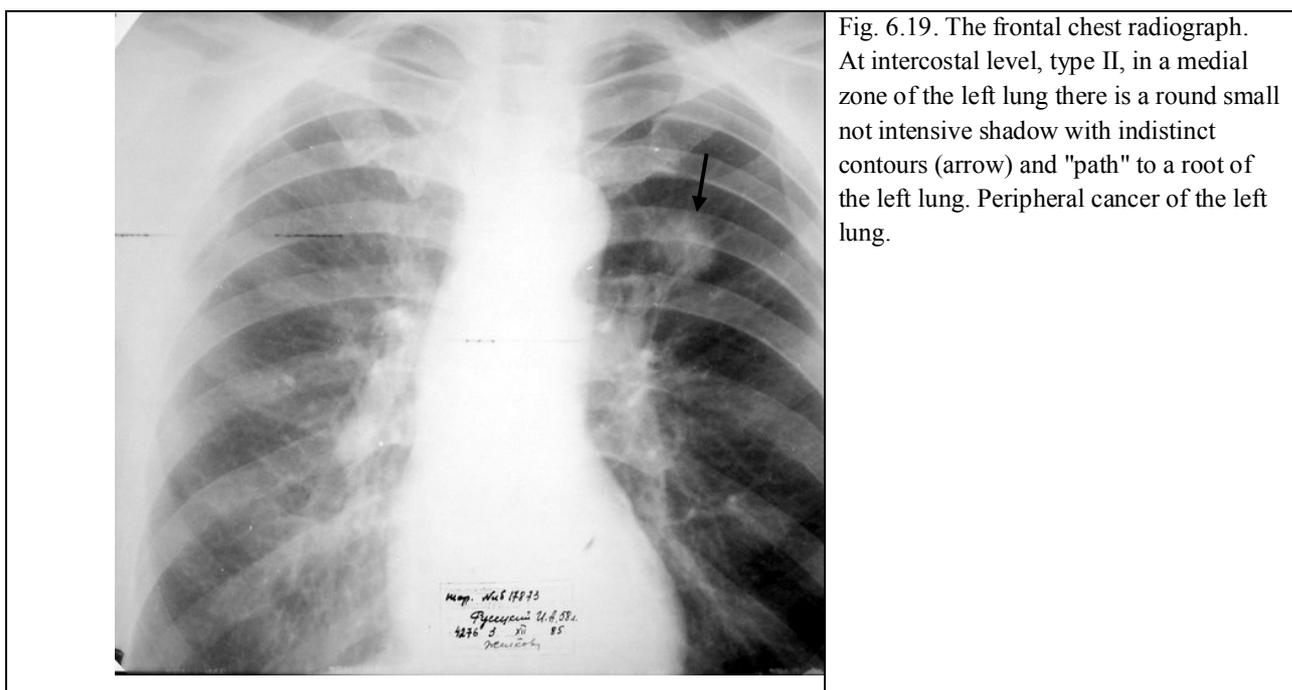


Fig. 6.18. The frontal chest radiograph. There is microfocal diffuse dissemination on the both sides along all pulmonary fields. Hematogenic disseminated (miliary) tuberculosis.

In spite of the fact that pathological changes in lung are commonly characterized by shadow with irregular form, sometimes regular-shaped shadows can be observed (round, ring-shaped, triangular, and linear).

During research spherical formations in lungs in direct and lateral projections are characterized by round shadows. Among the diseases producing round shadows, the following ones should be mentioned: peripheral cancer, tubercular infiltration, tuberculoma, metastasises of malignant tumours, echinococcus, mediastinal tumour, benign tumours, etc (fig. 6.19).



Ring-shaped shadow in lung corresponds to the lung cavity with air. On X-ray film the closed ring is detected in direct and lateral projections at fluoroscopy. Such form of the shadow can be caused by the tubercular cavern, decaying cancer, emptying abscesses, gas-filled cyst, cystic bronchiectasis (fig. 6.20).

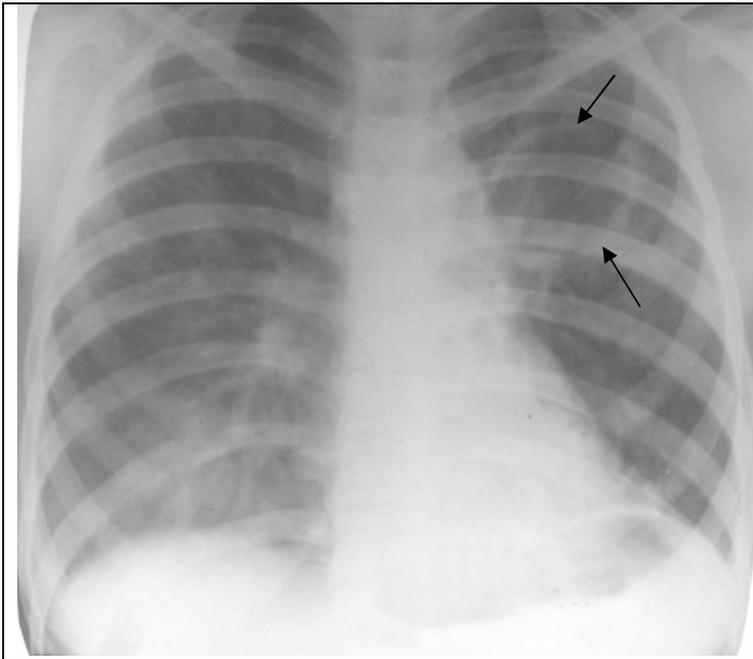


Fig. 6.20. Chest film. Ring-shaped shadow in pulmonary field (arrows). Walls in regular intervals thick. There is no liquid in the cavity. The cavernous form of pulmonary tuberculosis.

Segmentary atelectasis, pneumonias, mediastinal pleurisy, pulmonary infarction are characterized by triangular shadows (fig. 6.21).

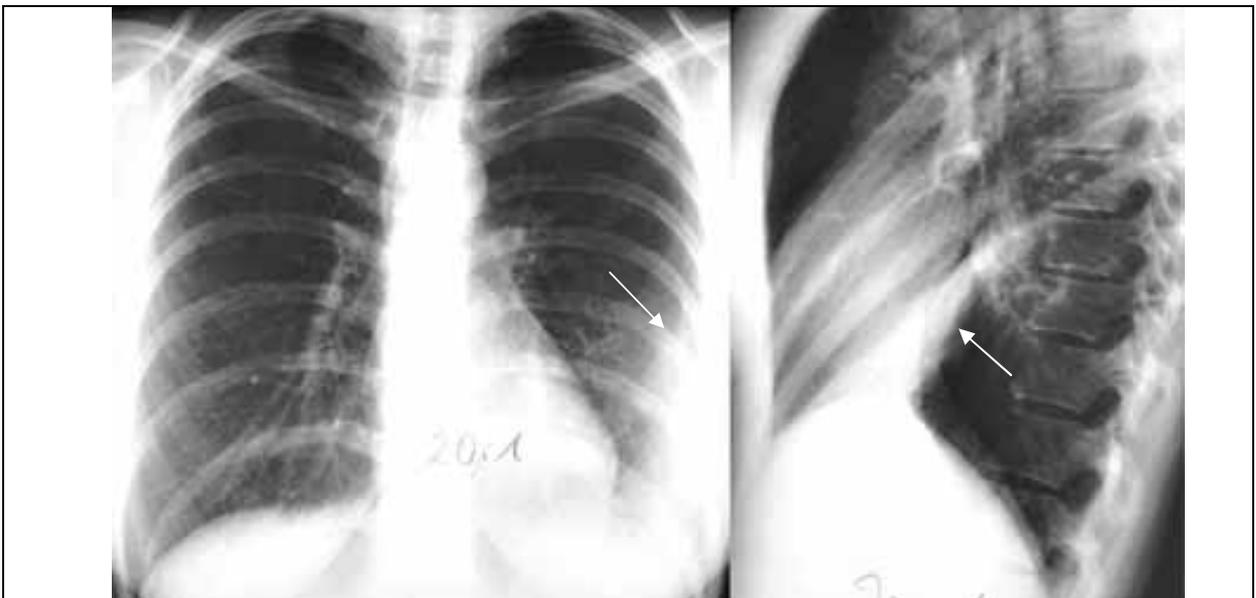


Fig. 6.21. Survey radiographs of a thorax in direct and lateral projections. There is a limited shadow of homogeneous structure, the triangular form (arrows) in projection VIII segment of the lower lobe of the left lung.

Pulmonary embolism in segment VIII of the lower lobe of the left lung.

Linear shadows in lungs can form at chronic inflammatory diseases following growth of connective tissues, at pleura thickening (fig. 6.14), at some kinds of pulmonary congestion.

According to the structure shadows are divided into: homogeneous (unstructured) and inhomogeneous. Atelectasis, exudative pleurisy, echinococcus cyst, lobar pneumonia in stages of hepatization produces a homogeneous shadow. Lung tumours, bronchopneumonia, abscessing pneumonias are characterized by inhomogenous shadows.

Shadow intensity depends on extent of pathological process in lungs and on pathomorphological substratum. The shadow is considered intensive when neither lung pattern, nor ribs shadows can be differentiated against its background. Shadows of small intensity are characterized by the presence of lung pattern against their background. The shadow of average intensity has no lung pattern. However ribs shadows are differentiated against its background.

Contours of a shadow in lung are often blurred, gradually turning into normal pulmonary tissue. It can be observed at acute inflammatory processes. Clear smooth contour is typical for echinococcus cyst, suppurated aereocele, inflammatory process within one lobe, whose shadow is distinctly limited by interlobar fissura. Clear smooth contour is developed by tuberculoma, peripheral lung cancer.

Increased lung transparency can be observed at various diseases. It can be diffusive, bilateral, unilateral or local.

More intensive radiolucency in both pulmonary fields is caused by the increase of pulmonary tissue in patients with emphysema, bronchial asthma, chronic bronchitis.

Increase of transparency of lung, and its lobes is caused by their ventilation disorders (valve corking of bronchi) or pneumothorax; at the latest there are no elements on pulmonary image in general. The local radiolucency symptom is provided by gas-filled cyst. Cavities in lungs containing air (tubercular cavern, decaying peripheral cancer, emptied abscess, cystic bronchiectasis, air in pleural cavity) are signs of local radiolucency.

The characteristic of lucent is carried out under the same circuit and sequence, as shadow.

The characteristic on position of a cavity matters for topical diagnostics - the cavity is outside of or inside lung and for differential diagnostics.

The characteristic on number of cavities. Single cavities are characteristic for a chronic abscess lung, a breaking up cancer. Plural cavities are at bronchiectasia, at cavernous a tuberculosis.

In the form of a cavity can be correct, ring forms at the generated tubercular cavity and wrong – at abscesses, bronchiectasia.

The sizes of cavities. It is accepted to divide cavities on fine (diameter of 1,5 cm), average (1,5-5 cm), large (up to 8 cm) and huge (from above 8cm).

Figure (structure) of a cavity. It is necessary to understand a condition of walls, contents of a cavity and surrounding tissue as this definition. Air cavities can be without liquid contents and with a liquid. The horizontal level of a liquid above which air settles down will be defined, happens at the generated abscess lung in later stage.

Very seldom at a tuberculosis, an abscess and a breaking up cancer in a cavity, except for a liquid, there can be a slice necrotizing and come off from a great bulk pulmonary tissue - the sequestration. Air cavities without a liquid, as a rule, happen at cysts a lung; at a tuberculosis also there is not enough liquid in cavities (fig. 6.20 and 6.22).

Condition of walls of a cavity. Walls cavernous formations can be as thin-walled capsules, the fibrous, precisely outlined rings or as the expressed inflammatory process with not well defined borders, lung cancer with destruction has non-uniform thickness of a wall, tuberculosis cavity, as rule, has uniform thickness of a wall. The syndrome of the limited radiolucent represents local increase of a transparency of a pulmonary field. Its form can be ring shaped or wrong. The intrapulmonary processes causing this syndrome are, abscesses, bullous emphysema (fig. 6.23), destructive cavity of a peripheral cancer, destructive forms of a tuberculosis of lungs, empty abscess, bronchiectasis. External lung the diseases shown by this syndrome: pneumothorax, diafragm hernias. The local symptom of a lucent gives air cyst.

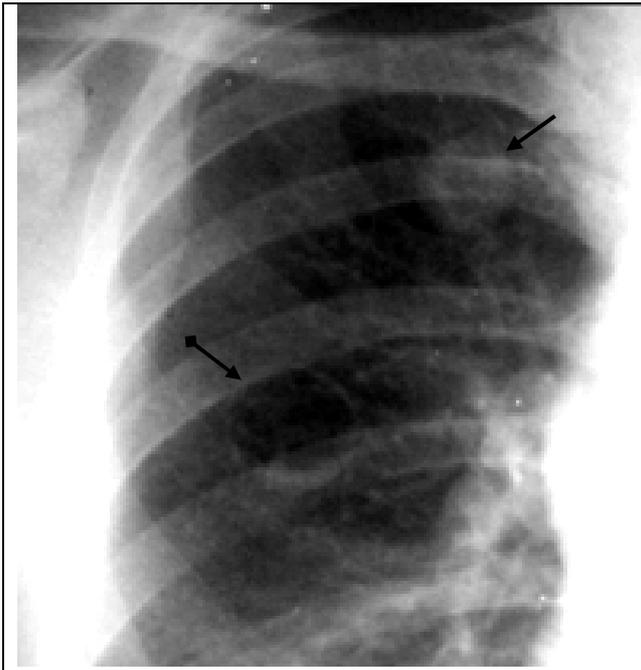


Fig. 6.22. Enlargement of a thorax in direct projection. Under clavicle to a zone of the right pulmonary field a round shadow with the accurate smooth contours, homogeneous, average intensity (arrow). In the right pulmonary field ring-shaped a shadow with accurate, thin, equal walls, at the bottom pole of this shadow a small congestion of a liquid with horizontal level (an arrow with a rhombus). Filled and emptied cysts the right lung.

Sometimes the so-called huge cyst occupies almost entire lung and increases its transparency (fig. 6.23).

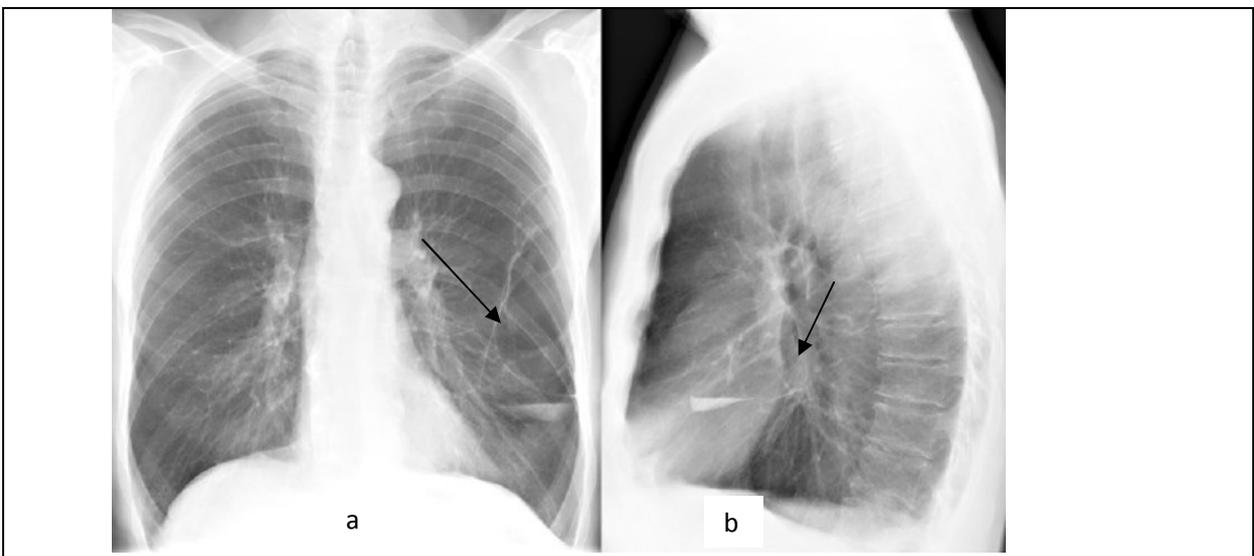


Fig. 6.23. Survey radiographs of lungs in a posterior-anterior (a) and left lateral projections (b). The limited radiolucent zone with horizontal level of a liquid (arrow) in lateral part of the left pulmonary field of incorrectly oval form with thin accurate walls, lateral wall merges with a chest wall. Huge bullous emphysema the left lung.

Change of lung pattern. The majority of pulmonary diseases are accompanied by change of lung pattern: intensification, attenuation, deformation.

Intensification of lung pattern is caused mostly by disorders in pulmonary blood flow, and is characterized by increase in number of elements on the pulmonary

image, denser network of vessels' branches. Intensification of pulmonary image can be observed at acquired and congenital heart diseases with increased blood flow, at acute inflammatory processes.

Attenuation of lung pattern (diminution of its elements) is observed at emphysema, huge air cyst, at the congenital heart diseases with reduced pulmonary blood flow (Fallot's tetrad, stenosis of pulmonary artery ostium, etc.) (fig. 6.24).

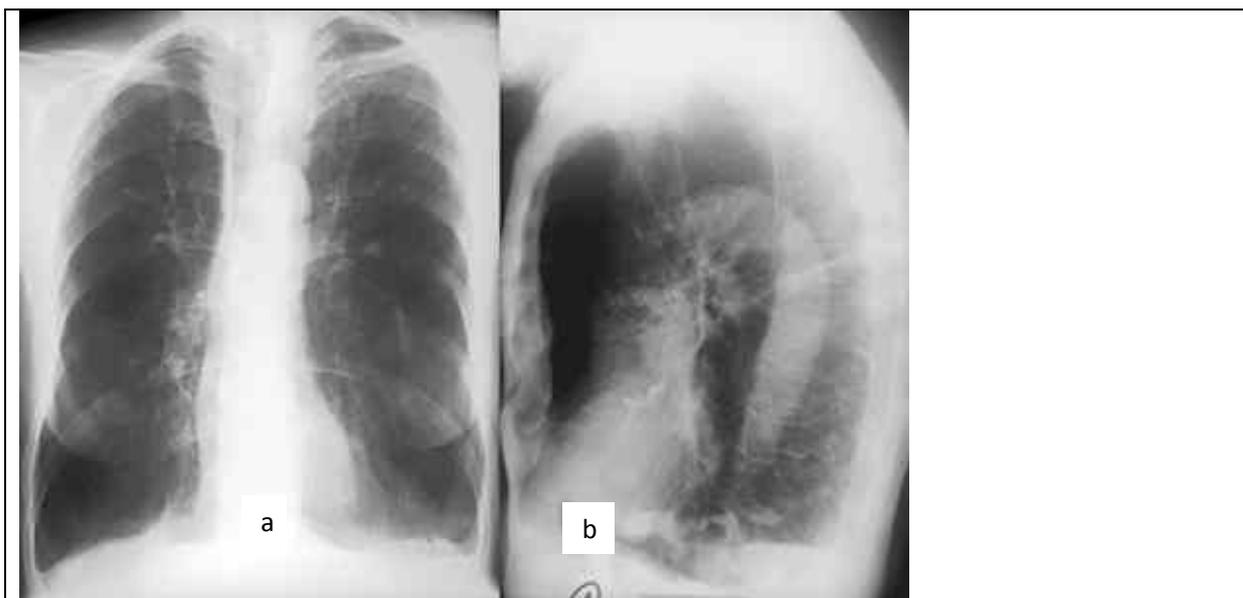


Fig. 6.24. Survey radiographs of lungs in direct (a) and lateral (b) projections. Deformation of a thorax similar a barrel, expansion of intercostal intervals, low standing of domes of a diaphragm. Increase of pulmonary fields in sizes. Pauperisation of pulmonary drawing. Emphysema of lungs.

At pneumothorax there is no image of blood vessels of lungs (fig. 6.25).

Intensification and deformation of lung pattern are caused by growth of connecting tissue around the vessels, bronchi, interlobular and interacinus septa. Such changes can be observed at chronic bronchitis, pneumosclerosis of tubercular and non-tubercular aetiology, bronchiectasis, etc.

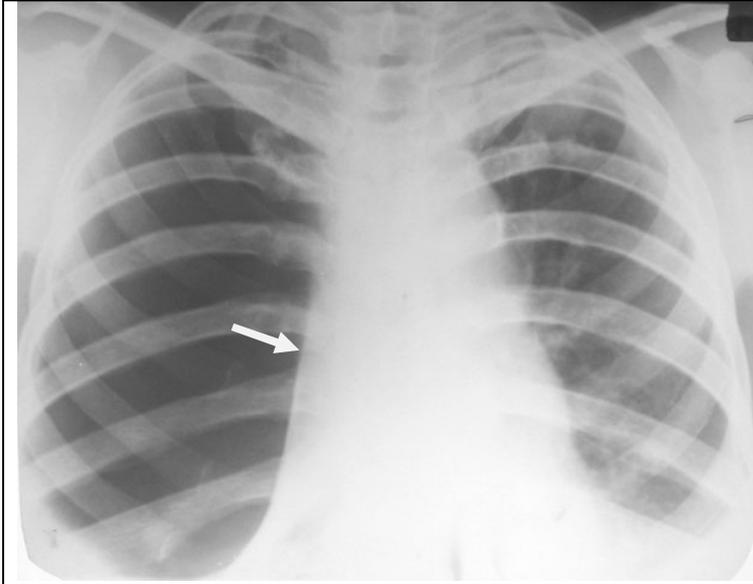


Fig. 6.25. Anteroposterior radiograph shows asymmetrical hyperlucency in the right pulmonary field. Compression atelectasis of right lung (arrow). Pneumothorax.

Changes in lung roots. Many pulmonary diseases are accompanied by change of lung roots (hilum pulmonis) and, first of all, their enlargement. Enlargement of lung roots can be unilateral, e.g., at sharp inflammations, and bilateral. Bilateral enlargement of roots lung without change of their structure and position is observed at the increased blood flow in lesser circulation at some acquired and congenital malformations. Enlargement of roots in these cases is accompanied by intensification of pulmonary vessels and change of a configuration of heart (fig. 6. 26). Enlargement of lung root is promoted by increase in lymph nodes (fig. 6.27). Polycyclicality of contour of the enlarged lung root in the adult person indicates tumoral lesion of lymph nodes.

Fibrous changes of lung root correspond to fibrous changes in lung (fig. 6.14).

Relocation and mobility disorders of diaphragm.

Pulmonary diseases which are accompanied by reduction of lung or its lobes following development of cirrhosis, fibrothorax of different origin, atelectasis, as well as absence of a lobe or the entire lung following surgery, are characterized by high position of diaphragm. It can also be observed at relaxation, paresis and paralysis of diaphragm. Sometimes high position of a diaphragm is caused by tumour growth in subdiaphragmatic organs. Low position of diaphragm is observed when the entire lung or its part is increased (emphysema, bronchial asthma).

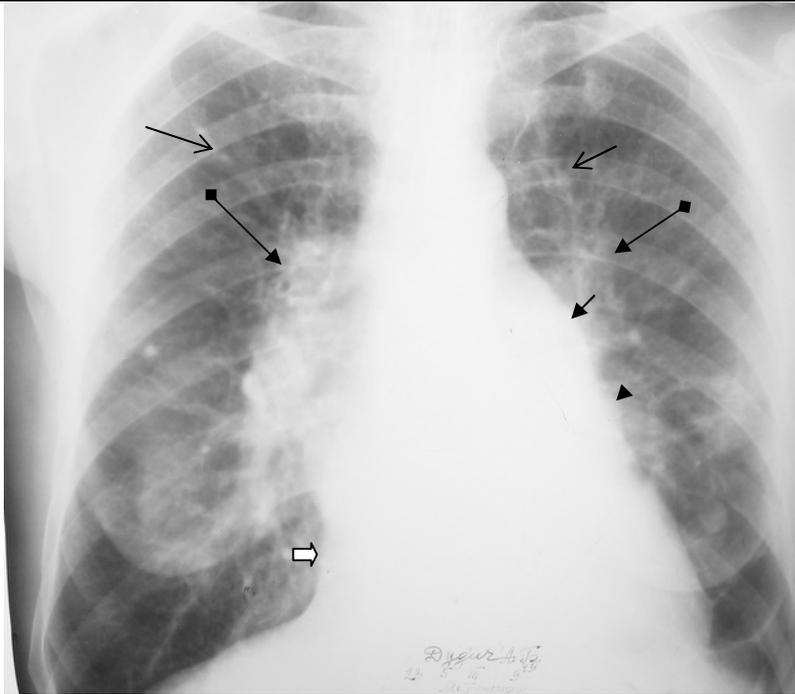


Fig. 6.26. The frontal chest radiograph. Shades of roots of lungs are increased at the expense of expansion of vascular trunks forming them (an arrow with a rhombus). Lung pattern is intensified from both sides, mainly in upper departments (open arrows). The heart shadow is expanded (mitral configuration). Increase in arches on the left contour: pulmonary artery (black arrow), the left atrium (small black arrow), left ventricle (white arrow). The increased left atrium forms an additional arch on the right contour of heart (figured arrow).

Mitral insufficiency. Signs of venous stagnation in lesser circulation.

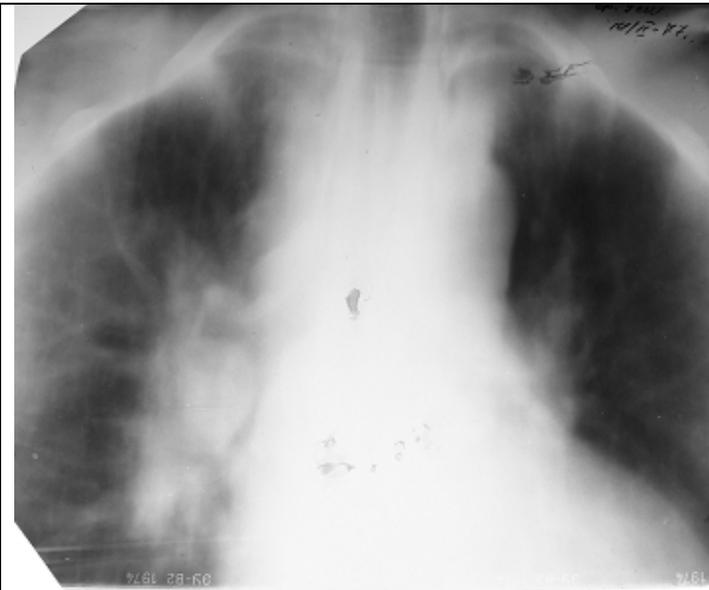


Fig. 6,27. Fragment of the conventional tomogram of a thorax in direct projection at the level of bifurcacio tracheas. The root of the right lung is expanded, its external contour polycyclic (arrow). A tuberculosis of lymph nodes of a root of the right lung

6.7. Radiological signs of acute inflammatory processes in lungs

Currently there is no uniform classification of types of acute pneumonia. Many researchers prefer to divide acute pneumonic processes according to the etiological basis.

Pneumococcal pneumonia. Lobar pneumonia is the most well-known. Lobar pneumonia is the result of alveolar wall injury with severe haemorrhagic oedema induced by inhaled infectious organisms that reach the subpleural zone of the lung. The process leads to consolidation of an entire lobe or segment. It is characterized by the acute onset, severe course, sequence of pathologicoanatomic changes. Infection that gets into the body aerogenically at presence of some predisposing factors (cooling, overfatigue, etc.) affects the entire lobe lung or part of it. In clinical and pathologicoanatomical terms pneumonia is characterized by interchange of four stages of development.

The stage of inflow or hyperemia involves overflow of a lung lobe with blood, capillary dilatation, accumulation of serous fluid with erythrocytes and leukocytes in alveoli. Duration of this stage is about one day. Typical features of this stage of pneumonia are: lung pattern of the lobe enhances, insignificant reduction in transparency in 2-3 days, enlargement of a lung root, sometimes the linear shadow of interlobe pleura, restraint of movement of diaphragmatic cupula. In 2-3 days hyperemia stage turns into red hepatization stage. Cavities of alveoli are filled with fibrin with erythrocytes, leukocytes, alveolar epithelium, that results in lobe increasing in size and density.

Red and grey hepatization stages are characterized by the intensive almost homogenous shadow of affected lung lobe. Its intensity increases towards the periphery. The lobe usually has common sizes, often with enlarged lung root, whose structure is lost. The lobe decreases at atelectasis. Besides, shadowing at lobar pneumonia differs in two more features: first, intensity of shadow increases towards the periphery; second, that on its background in medial departments are visible radiolucent a strip of bronchial tubes of large and average sizes (this sign be possible mean as air bronchogram – air bronchogram, visualization of air within normal intrapulmonary bronchi caused by consolidation in adjacent alveoli providing tissue contrast between lucent airways and opaque lung) (fig. 6.28).

Adjacent pleura is condensed, sometimes pleural effusion can be observed (fig. 6.29 and 6.30). There are no radiological distinctions between red and grey stages of hepatization.

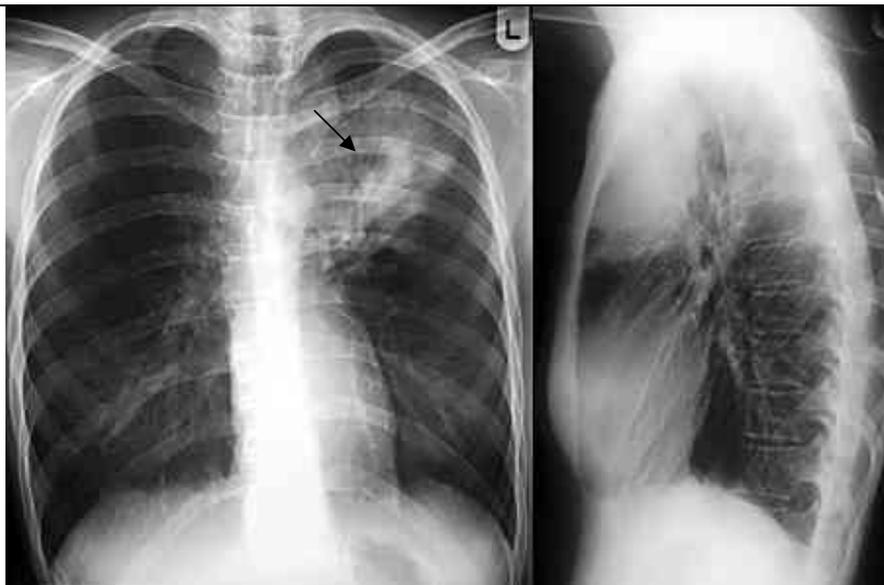


Fig. 6.28. Survey radiograph in frontal and lateral projections. Extensive shadowing of left pulmonary field, air bronchogram (arrows).
Acute pneumonia of the upper lobe of right lung.

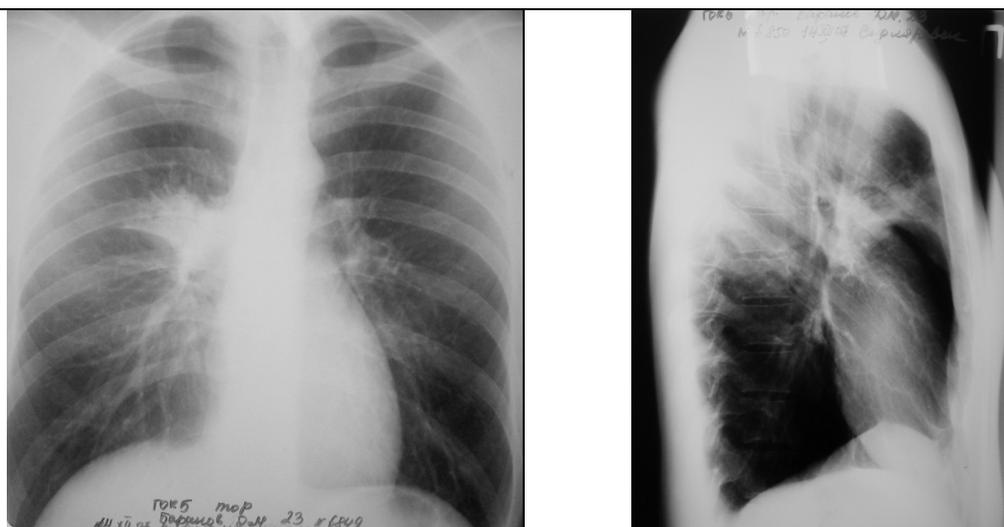


Fig. 6.29. Survey radiographs of the 23-year-old patient's thorax in frontal and right lateral projections. The limited shadow in the forward (III) segment of the upper lobe of the right lung. Shadow has average intensity in the medial part and small intensity on the peripheries, its contours are indistinct, except for the bottom border adjoining the interlobe fissura. The lung root on the right is expanded. Acute right pneumonia with affection of the anterior segment of the upper lobe of the right lung by analogy with periscissuritis.

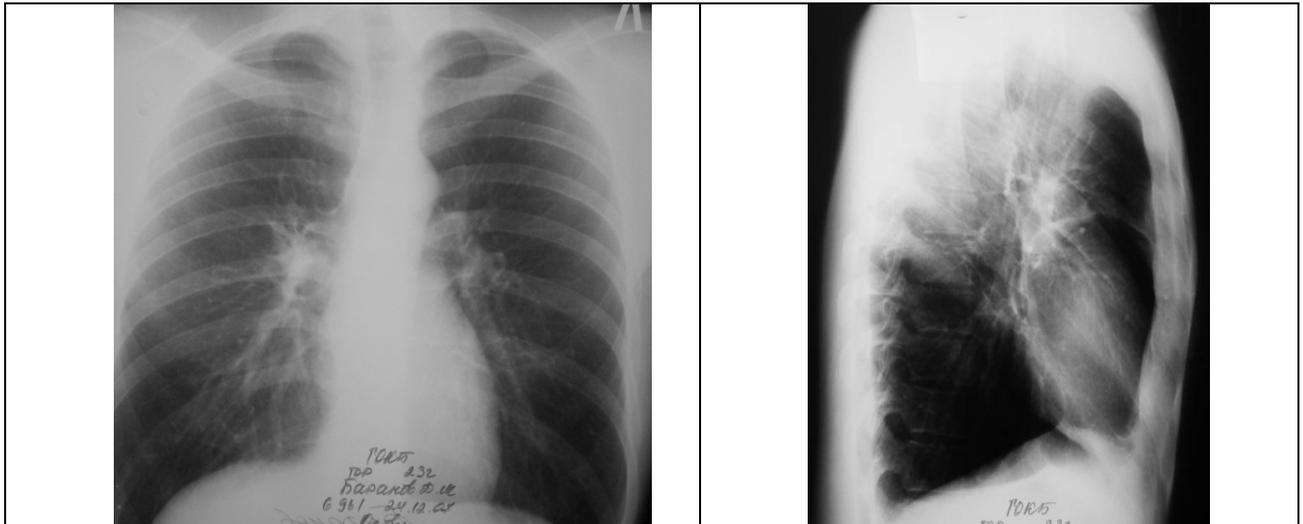


Fig. 6.30. The same examination as in the previous images, but in 10 days after the treatment. Positive dynamics. Infiltrative shadow in the anterior segment of the right lung disappeared. Induration of interlobar pleura on the right still remains (between the upper and medial lobes). Acute pneumonia of the right lung on the convalescent stage.

The convalescent stage is characterized by gradual decrease in intensity of a shadow, its fragmentation and reduction in sizes. The shadow of a root remains enlarged and non-structured. The same concerns lung pattern on the place of former hepatization: it remains enhanced during 2 - 3 weeks after clinical recovery. Complications, unfavorable outcome (incl. abscessing pneumonia with bronchiectasis, cirrhosis) are possible.

Bronchopneumonia. Its causative agent is pneumococcus. Lobules are involved in inflammatory process at bronchopneumonia. Unlike lobar pneumonia, the clinical course is less severe, the onset is gradual, temperature is usually not high. Bilateral lung affection with focal shadows corresponding to the lobules sizes (1.0 cm), with indistinct contours of small or average intensity is typical at radiological research. The highest number of foci is located in the inferior lung departments. Through the entire lung lung pattern intensification is observed, roots are increased. Pleural reaction is possible, as well as development of exudative pleurisy. At bronchopneumonia foci can fuse followed by the development of large inflammation loci. Bronchopneumonia can be characterized by small focal shadows. One of the typical features of bronchopneumonia is fast dynamics of focal shadows during the first week and disappearance of foci is observed in 10-14 days (fig. 6.31 and 6.32). It is the main difference from tuberculosis.

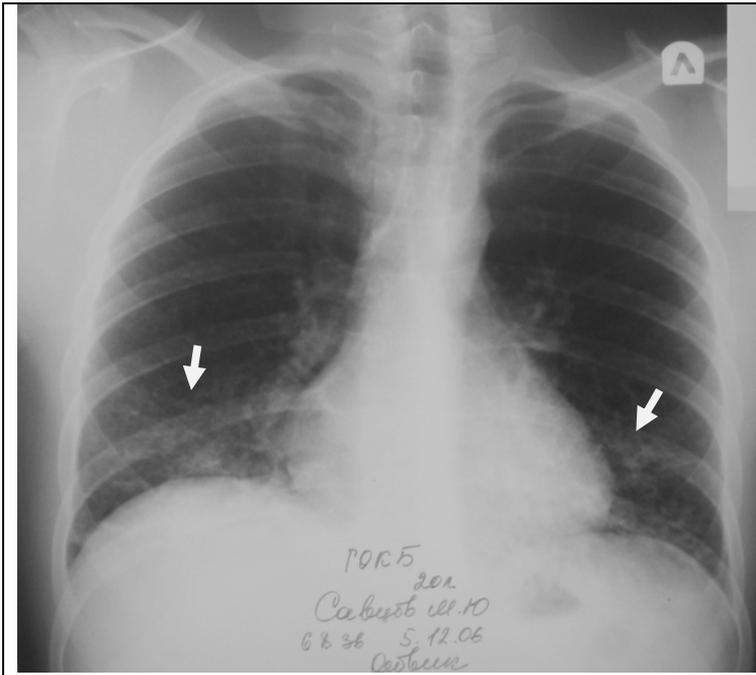


Fig. 6.31. Focal shadowing in the lower lobes (arrows).



Fig. 6.32. Disappearance of focal shadowing in the lower lobes in 10 days of treatment.

Streptococcal and staphylococcal pneumonias. Make up about 10 % of all types of acute pneumonia. These types of pneumonia are more prone to occur in children, including those of younger age and infants.

Primary staphylococcal and streptococcal pneumonias in adults can clinically proceed in two ways.

The only way to distinguish staphylococcal type of pneumonia from the streptococcal one is the bacteriological analysis.

The radiological image of strepto -and staphylococcal pneumonias is characterized by presence of numerous inflammatory foci of large and average sizes, usually in both lungs. Outlines of foci are indistinct, intensity of shadows depends on their sizes; the tendency towards their fusion and following disappearance can be observed. In such cases radiolucency appears against the background of shadows of inflammatory foci. These radiolucencies are delimited below by horizontal fluid level. radiolucent, often be present air-fluid level. Relatively fast change of radiological image is typical. Within 1-2 weeks (or longer) occurrence of infiltrations can be observed, their decay, transformation of decaying cavities into thin-walled cysts with their subsequent reduction. One X-ray film can reveal all stages of development pneumonic infiltrates, what makes radiological image look peculiar.

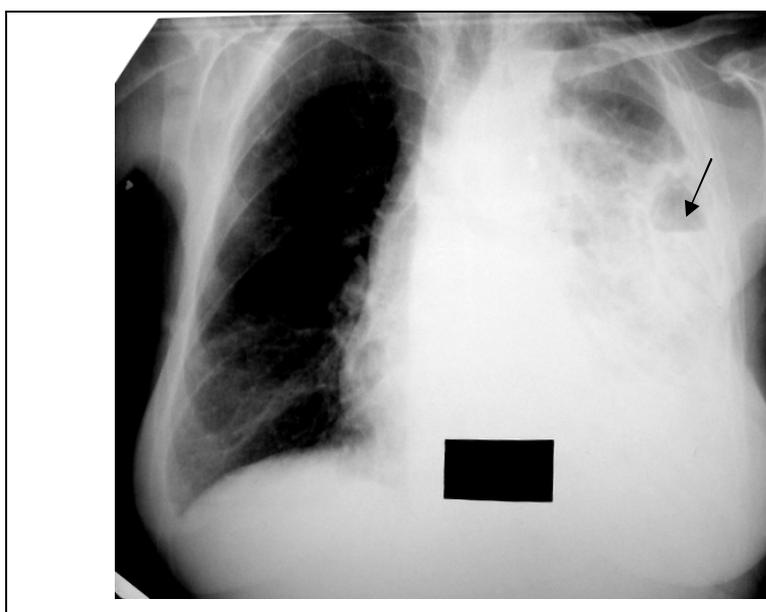


Fig. 6.33. The frontal chest radiograph.

The total non-uniform shadow in the left pulmonary field, in the top department of average intensity with an indistinct contour, in the bottom department with high intensity, on this background is available a hyperlucency (arrow) with horizontal level (a disintegration cavity). The dome of a diaphragm and sine at the left are not differentiated. Mediastinum it is displaced to the right. A staphylococcal pneumonia of left lung. Pleural effusion in the left side.

Viral pneumonia. The most common cause of it is influenza virus. The main clinical presentations are: pains in a thorax, moist cough, general weakness. Low-grade fever is common, though sometimes the temperature can rise up. Blood count is characterized by leukopenia, sometimes by lymphocytosis. Clinical peculiarity of acute interstitial pneumonia is its resistance to sulfanilamide and to most of antibiotics. There are 3 stages of radiological image of acute interstitial pneumonias: 1) initial, tracheobronchitis characterized by intensification of bronchial pattern. Substratum of these changes is inflammatory infiltration of interstitial tissue located

around bronchi, vessels, acinus, lobules, segments. There is a significant amount of shadows, and their usual radial orientation disappears. 2) Peribronchitis, when against the background of intensified pulmonary pattern multifocal uptakeshadows appear, especially in root and supradiaphragmatic departments. 3) pneumonic, when multifocal shadows are a basic element of a radiological image; large low-intensity infiltrates with indistinct outlines can develop; there is no pleural effusion (fig.6.34).

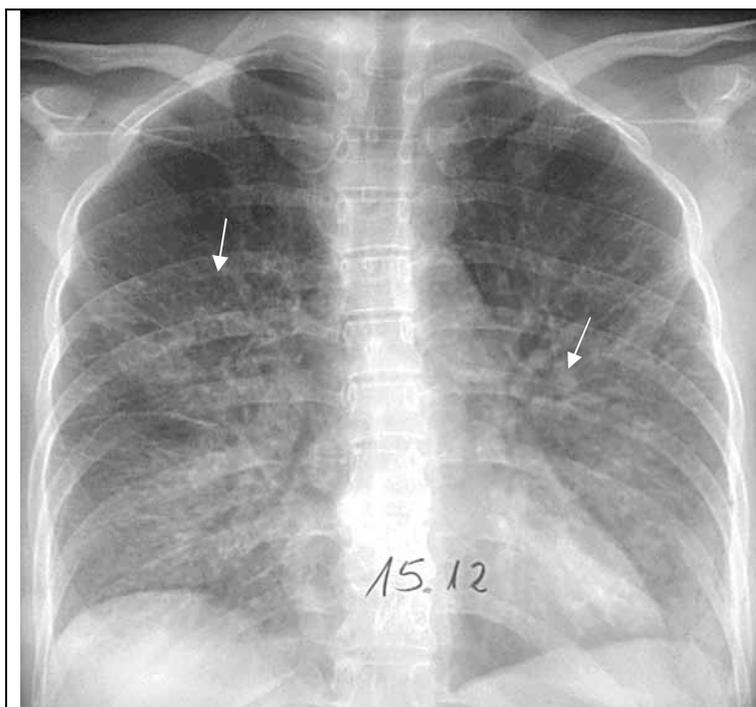


Fig. 6.34. The survey radiograph of a thorax in direct projection. Structure of roots of both lungs is indistinct. Lung pattern of both lungs is intensified and deformed in the middle and inferior departments with developing of cellular structures (arrow). In the root region of left lung focal shadows of small intensity (arrow with rombus). Viral pneumonia.

Clinical course of interstitia pneumonias is long: radiological changes are observed within 3-6-8 weeks and more. When progressing favourably, acute viral pneumonia resolves completely and normal radiological picture is restored. When the disease progression is prolonged, hardening of the pleura and of the pneumosclerosis areas can be observed as residual effects. Quite often chronic bronchitis, diffusive pneumosclerosis, bronchiectasis develop.

Dynamics of roentgenological picture, sputum analysis, immunological examinations enable to diagnose correctly.

Septic pneumonias are acute inflammatory processes in lungs following hematogenic bringing of infection from single purulent foci (osteomyelitis, liver abscess, furuncle). Staphylococci, or more seldom streptococci and colon bacillus, are causative agents.

Groups of microbes first get into the blood flow, in lesser circulation, settle in small pulmonary vessels, bringing on their thrombosis with the subsequent transition of inflammatory process to a pulmonary fabric. In a lung there is an inflammatory focus from which the further distribution of process goes on lymphatic ways. There are no typical clinical presentations of septic pneumonia. X-ray examination detects extensive bilateral defeat of lungs, numerous nodular and infiltrative shadows. The latest tend to disintegrate and develop abscess-like cavities, without horizontal levels (fig. 6. 35).

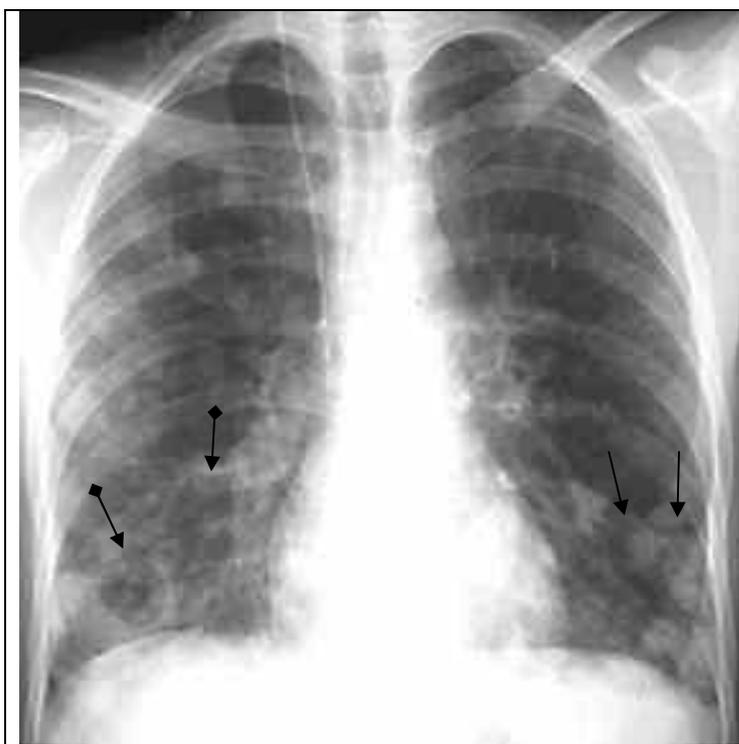


Fig. 6.35. The frontal chest radiograph. Plural roundish shadows with indistinct contours in the inferior department of a pulmonary field on the left (arrows). On the right in the inferior department of a pulmonary field the limited shadow, non-uniform with indistinct contours in which there is roundish radiolucency (arrow with a rhombus). Septic pneumonia with disintegration cavities.

CT. By means of CT it is possible at earlier stages at a sharp pneumonia to detect changes in pulmonary tissues, and also to establish localisation and prevalence of process more precisely. By means of CT the symptom of air bronchogram can be detected, which is typical for inflammatory indurations in pulmonary tissue. Absence of this symptom may indicate obstructive character of changes in lungs or destructive neurotic process.

6.8. Radiological signs of chronic nonspecific inflammatory processes in lungs

Chronic bronchitis. At acute inflammation of bronchi, radiological research is carried out not only to detect bronchitis, but also to eliminate the possibility of other pulmonary diseases, mainly pneumonia and bronchitis. In mild cases of acute bronchitis the pattern does not differ from the norm. In severe cases of bronchitis intensification of lung and root pattern can be identified. At chronic bronchitis the following pathological changes can be detected: 1) thickening of bronchial walls and increase of connecting tissue in lungs (pneumosclerosis); 2) lungs hyperinflation with symptoms of pulmonary hypertensia.

The second group of factors is typical only for diffusive obstructive bronchitis. Unchanged lung pattern does not necessarily indicate the absence of chronic bronchitis.

The thickening of bronchial walls is indicated as ring-shaped shadows of axial sections of bronchi. Thickness of the ring usually makes up less than 1 mm. When bronchus is located parallel to the x-ray film or at an angle to it, thickened walls can be seen as parallel lines (“tram rails”), each with width of less than 1 mm (fig. 6.36).

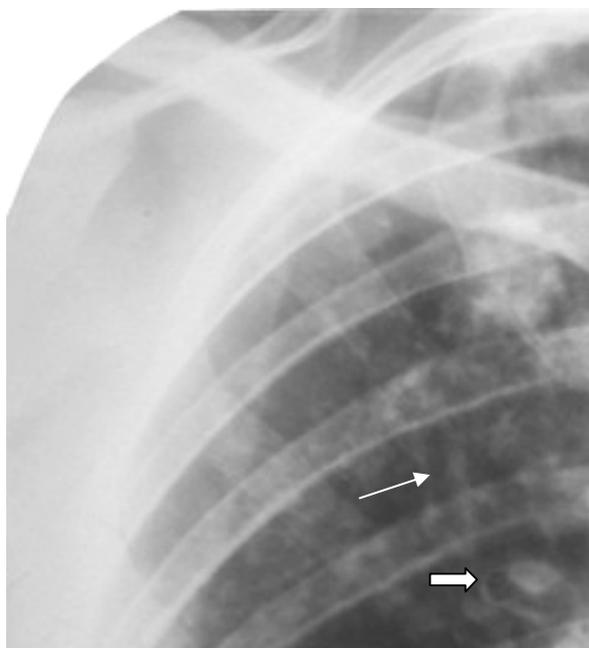


Fig. 6.36. Enlargement of chest in direct projection. Parallel linear shadows (arrow) and ring-shaped shadow (thick arrow) caused by peribronchial development of connective tissue. A chronic bronchitis.

The thickening of bronchial walls is combined with other changes of lung pattern, first of all, with symptoms of diffusive interstitial fibrosis. On the images it is developed as reticulate trabecular meshwork by figure and is caused by thickening of alveolar and interlobular septum (fig. 6.37).



Fig. 6.37. The frontal chest radiograph.
Diffusion bilateral strengthening and "mesh"
deformation of lung pattern.
Chronic bronchitis.

Symptoms of pulmonary emphysema and pulmonary hypertension are detected on the radiographs more seldom, e.g. thorax enlargement, thorax protrusion, enlargement of pulmonary cone, attenuation of peripheral lung pattern, thickening and low position of diaphragm, small cardiac shadow.

6.9. Radiological signs of respiratory tuberculosis

It can produce any radiological syndrome. In general there are 12 clinical forms of tuberculosis. We will consider the most common of them. There are two stages of tuberculosis: 1) infiltration, dissemination, disintegration; 2) resorption, induration, cicatrization.

Primary tuberculosis. Tuberculous primary complex develops. It is a combination of specific pulmonary tissue injury (usually of limited character) and injury of intrachest lymph nodes involvement, mainly regional ones. The triad is typical for tuberculous primary complex: 1) primary focus (infiltrate) in pulmonary tissues; 2) regional lymphangitis is a thickened shadow (vascular path), proceeding towards the root (hilar region) and connecting with the shadow of hyperplastic lymph node; 3) regional lymphadenitis. Thus bipolarity, "dumbbell" forms (fig. 6.38).

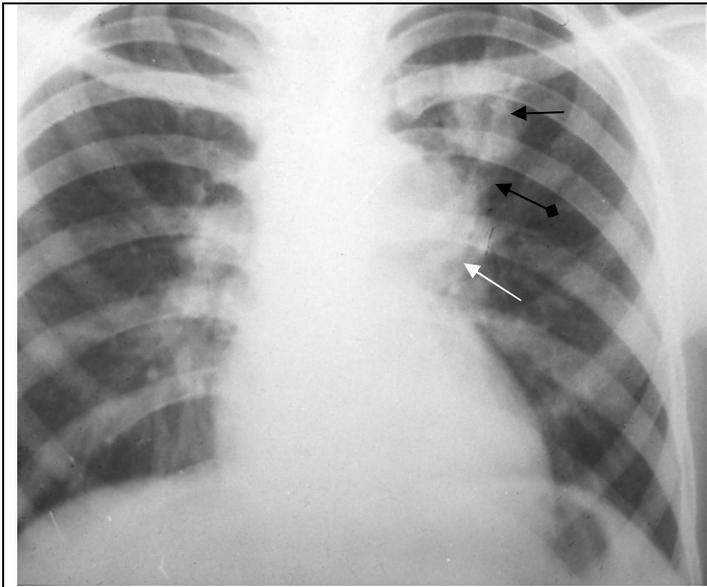


Fig. 6.38. The frontal chest radiograph. In the upper department of the left lung a roundish shadow with not absolutely distinct contours, non-gomogenous, and highly intensive (black arrow). The left hilum is enlarged; its external contour is convex (arrow with a rhombus). Between a shadow and a lung root there is intensification of lung pattern (white arrow). Tuberculous primary complex in the left lung in a phase of consolidation and calcification.

Tuberculosis of intrachest lymph nodes. In this case tomograms should be made. Types of tuberculosis of intrachest lymph nodes include: infiltrative, tumourous, indurative bronchadenitis.

Indurative bronchadenitis. It is characterized by development of inflammatory processes outside a capsule of lymph nodes, i.e. in pulmonary tissues. Enlargement and deformation of roots can be observed, the contour is indistinct, the structure is disturbed (fig. 6.39).

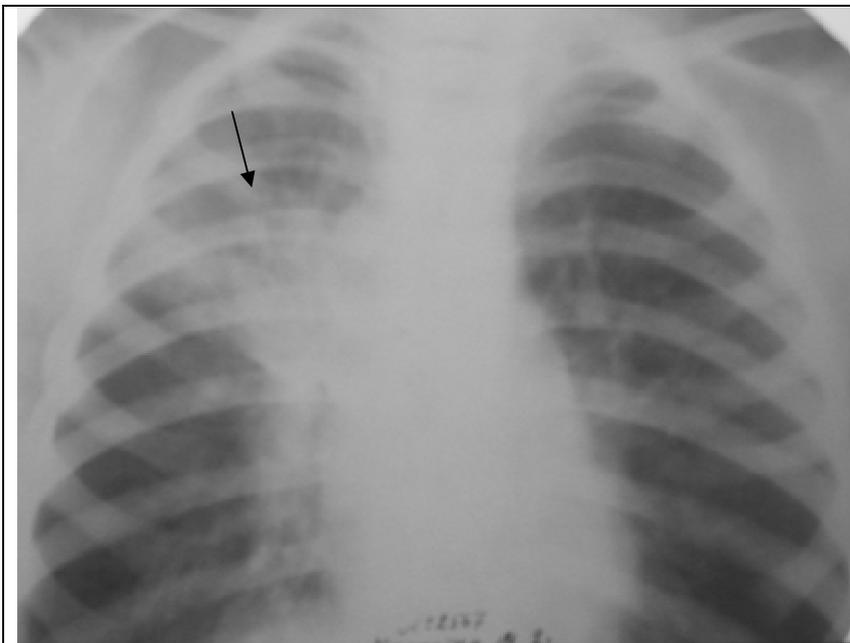


Fig. 6.39. The frontal chest radiograph. The frontal chest radiograph (the patient of 16 years). In the field of a hilum of the right lung the limited shadow with indistinct contours (arrow). The hypoinflation in projection of the right upper lobe. Primary tuberculous lymphadenitis on the right (infiltrative form).

Tumor-like bronchoadenitis. Condensation, deformation, enlargement of a shadow of a root arises with typical changes of the external contour acquiring polycyclic wavy character (fig. 6.40).

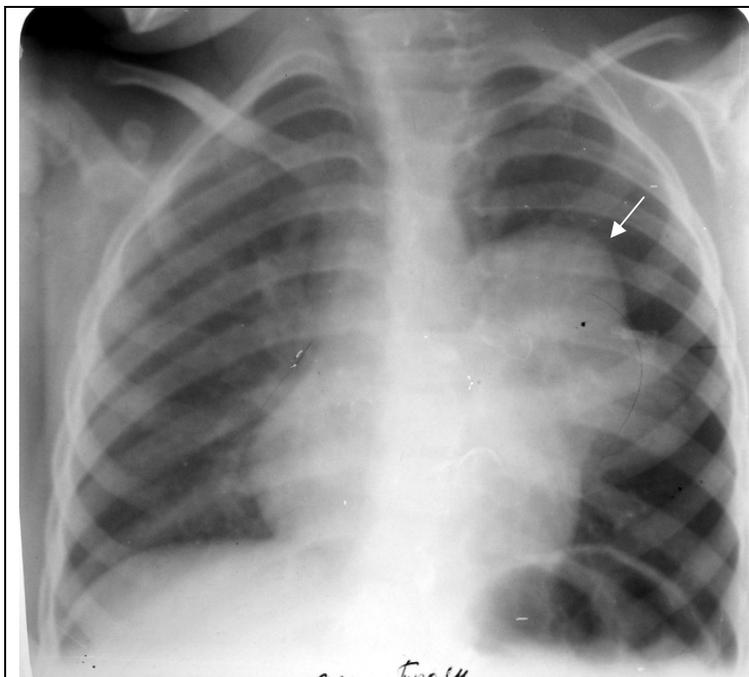


Fig. 6.40. At the left in the hilar zone a polycyclic shadow with accurate contours (arrow). Tuberculosis of intrachest lymph nodes of the left lung (tumoral form).

Indurative form of lymphadenitis is characterized by development of a fibrous connecting tissue in lymph nodes and by remains of specific inflammatory infiltration and of caseous mass.

Nodular tuberculosis. The radiographs reveal numerous multifocal shadows of different density, locating in groups in the upper departments of lung – in apex and subclavian areas (fig. 6.41).

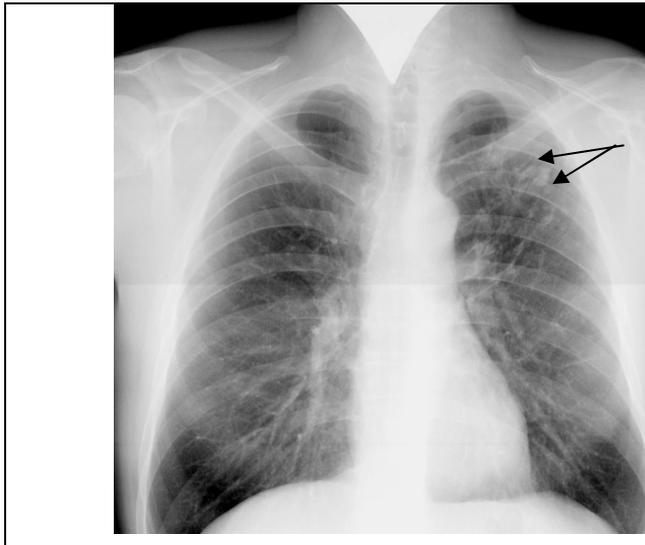


Fig. 6.41. The frontal chest radiograph. In the first intercostal space on the left lung nodular shadowing with mottled character (arrows). Nodular tuberculosis of the left lung.

Hematogenously disseminated tuberculosis. Is dynamic for a long time - 7-9 months.

On the radiograph miliary tuberculosis is identified as symmetric dissemination in all fields of small identical (1-2 mm) foci of equal density and sizes (fig. 6.42).



Fig. 6.42. CT-scan of thorax at the level of tracheal bifurcation. Microfocal diffusive dissemination is revealed in both lungs. Hematogenously disseminated (miliary) tuberculosis

Subacute lymphangitis is displayed as focal shadowings of different sizes and forms, of identical intensity, symmetrically located from both sides.

Chronic lymphangitis can be distinguished by dissemination of polytypic foci (with different sizes, forms, density) distributed through different parts of lungs; by marked pleural thickening and moving the roots upwards (fig. 6.43).



Fig. 6.43. The frontal chest radiograph. Against the background of intensified and deformed lung pattern in both pulmonary fields diffusive dissemination of nodular shadows of different sizes and intensity can be observed (arrows indicate separate nodular shadows). Chronic hematogenously disseminated tuberculosis.

Infiltrative pulmonary tuberculosis. Infiltrative tuberculosis can proceed acutely, clinically it can be similar to flu or pneumonia, however onset of tuberculous process is delayed, mycobacterium tuberculosis may appear in sputum. Low-intensity, indistinct opacity focus (oval or roundish), located in the upper departments of lungs and connected by linear shadows: a path with a root (fig. 6.44 and 6.45).

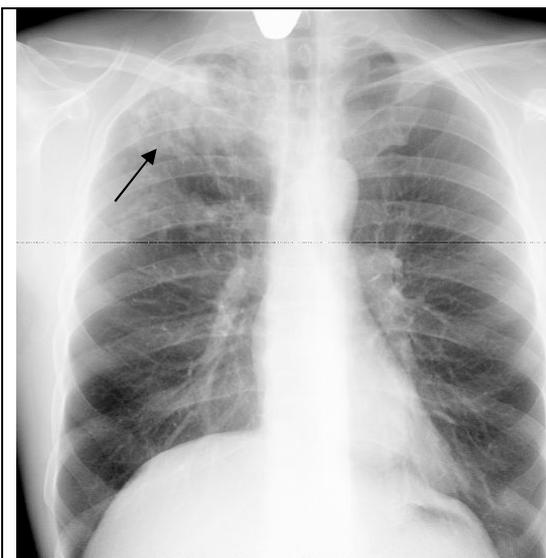


Fig. 6.44. In the upper department of the right lung the limited shadow of average intensity with indistinct contours (arrow). Infiltrative tuberculosis of the right lung.

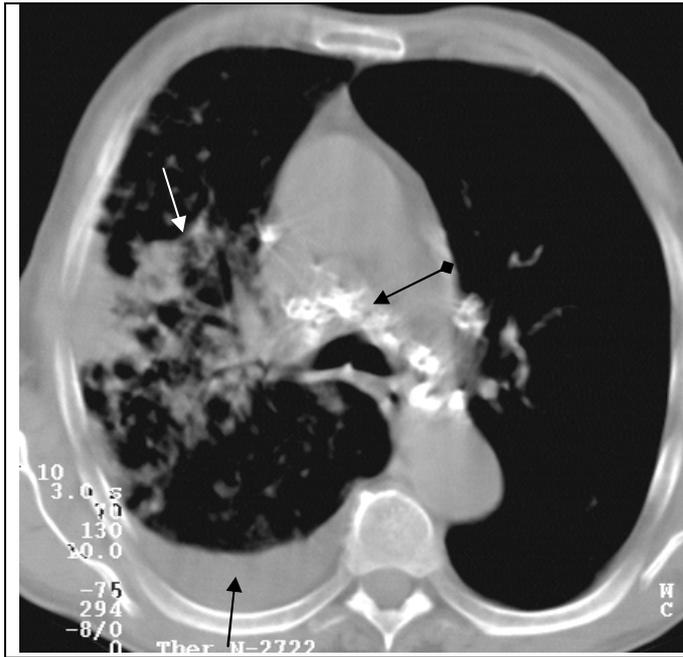


Fig. 6.45. CT-scan of thorax at the level of tracheal bifurcation. Nonhomogeneous increase of density of pulmonary tissue with indistinct contours within the upper lobe on the right (white arrow). Pleural effusion on the right (black arrow). Calcified lymph nodes of mediastinum (arrows with rhombus). Infiltrative tuberculosis of the upper lobe of right lung. Exudative pleurisy on the right

Tuberculomas are spherical formations with the diameter of more than 1 cm. Morphologically tuberculomas are foci of caseous pneumonia of various prescription surrounded by connective tissue fibrous capsule; isolated large focal shadow or small focus of intensive irregular-shaped opacity with rough or scalloped, but distinct contours. Tuberculoma frequently arises against the background of other tuberculous changes: nodules, calcification of pleural commissures, apical stratifications (fig. 6.46).

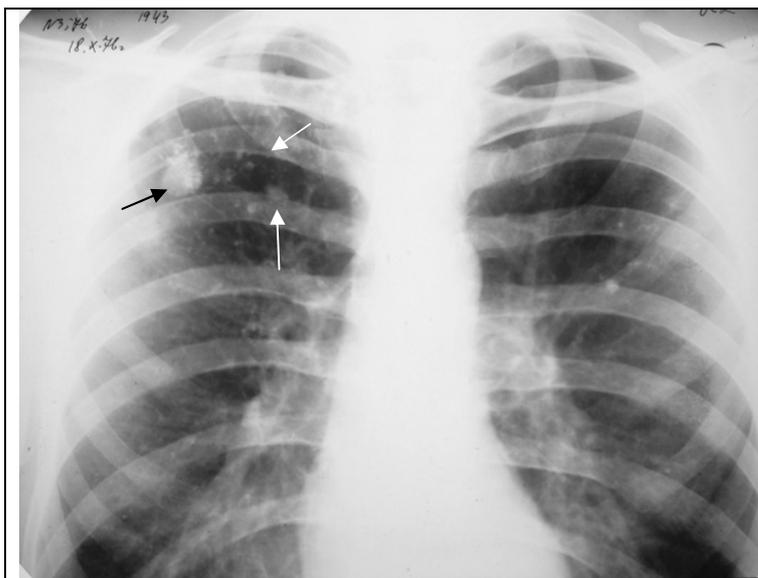


Fig. 6.46. On the right a round shadow of average intensity sized of 2 sm in diameter with distinct contours and intensive inclusions (black arrow). In surrounding pulmonary tissue middle nodular shadows of average and high intensity (white arrows). Tuberculoma of the right lung.

Cavernous tuberculosis. It is characterized by presence in lungs of isolated caverns without marked perifocal infiltration and fibrous changes in pulmonary tissue. Infiltrative, focal, disseminated forms can serve as the initial form. (fig. 6.47).



Fig. 6.47. On the left roundish shadow with uniform thickness of the wall (black arrow). Cavernous tuberculosis of the left lung.

The main symptom of cavern is a cavity of enlightenment without horizontal level of fluid with clear closed ring-shaped shadow, clearly outlined internal and external borders and with a shadow of drainage bronchus connected with a root, without marked signs of pneumosclerosis and fibrosis in surrounding pulmonary parenchyma.

Fibrotic cavernous pulmonary tuberculosis. It is the most dangerous form of tuberculosis since patients in most cases are eliminators of bacilli. Clinically this form of tuberculosis takes long and quite, often wavy course with change of the period of tuberculosis onset for the period of clinical well-being. Radiographic image: the caverns against the background of marked fibrosis of pulmonary and surrounding tissue, with deformation of lung pattern, thorax, narrowing of pulmonary fields, shift of mediastinal organs and pleural commissures. As a result of frequent exacerbations pulmonary changes are polymorphous (fig. 6.48).

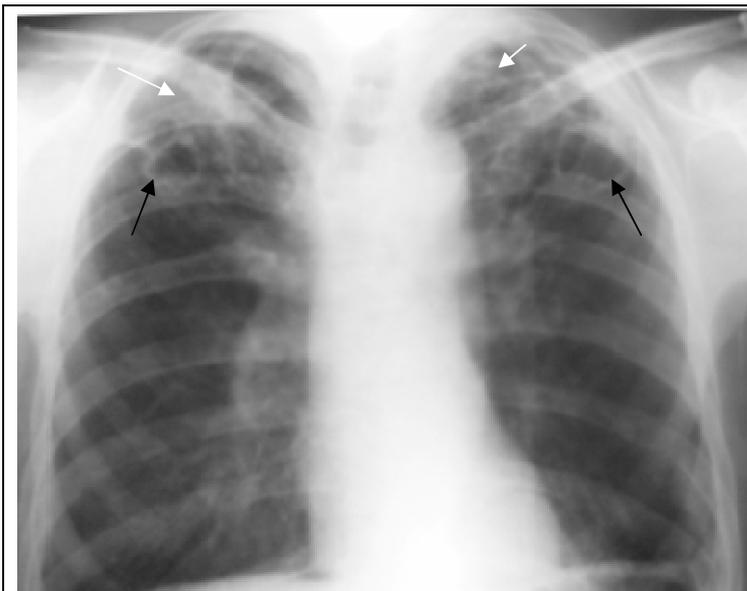


Fig. 6.48. In the upper part of right and left lung ring shaped shadows without presence of fluid (black arrows) and non-homogeneous shadows with average intensity and distinct contours (white arrows). Fibrotic cavernous tuberculosis of both lungs

Pleurisies (mostly of tubercular or malignant origin). Depending on quantity of fluid, shadow will be intensive, homogeneous, of triangular shape with concave and indistinct upper contour or total opacity. This shadow is located above diaphragm and shifts when the patient changes his position. When commissural process develops, encapsulation occurs, the effusion loses ability to shift, the shadow gets the special form and localization (fig. 6.49).

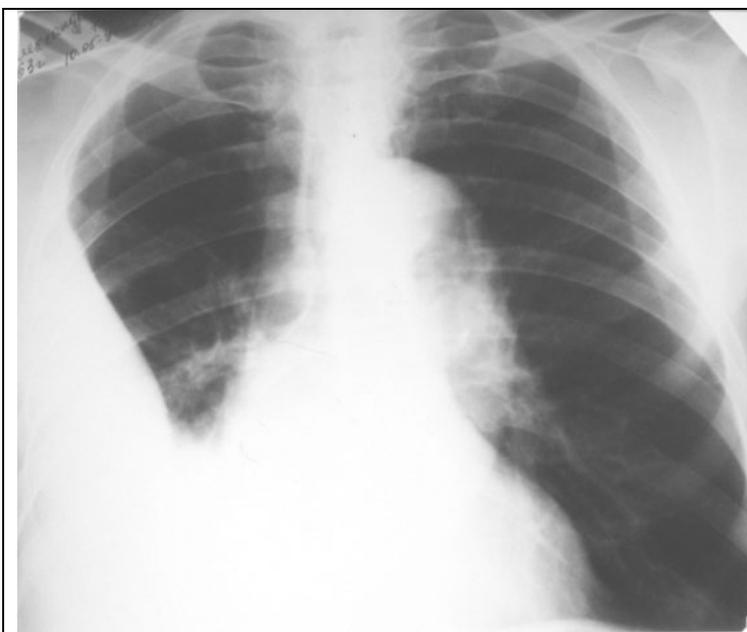


Fig. 6.49. Chest film. Pleural fluid. The hemidiaphragm outline is obscured and there is homogeneous opacification of the lower hemithorax associated with a triangle shape of the fluid at its upper, lateral margin. May be the only manifestation of primary tuberculosis.

Tuberculosis with fibrosis of lungs. Tuberculosis with fibrosis of lungs is characterised by the reduction of the injured lung at the expense of development of

sclerous changes in it (cicatrization atelectasis), at preservation of activity of tubercular process. More often fibrosis changes arise in the upper lobes of lungs. The basic radiological sign is reduction of the injured sites and their non-homogeneous shadow. It is caused by the development of cicatricial changes in pulmonary tissue, presence of nodular shadows of the various sizes and intensity, residual cavities. The lung root is deformed, condensed, displaced towards the injured department of a lung (fig. 6.50).

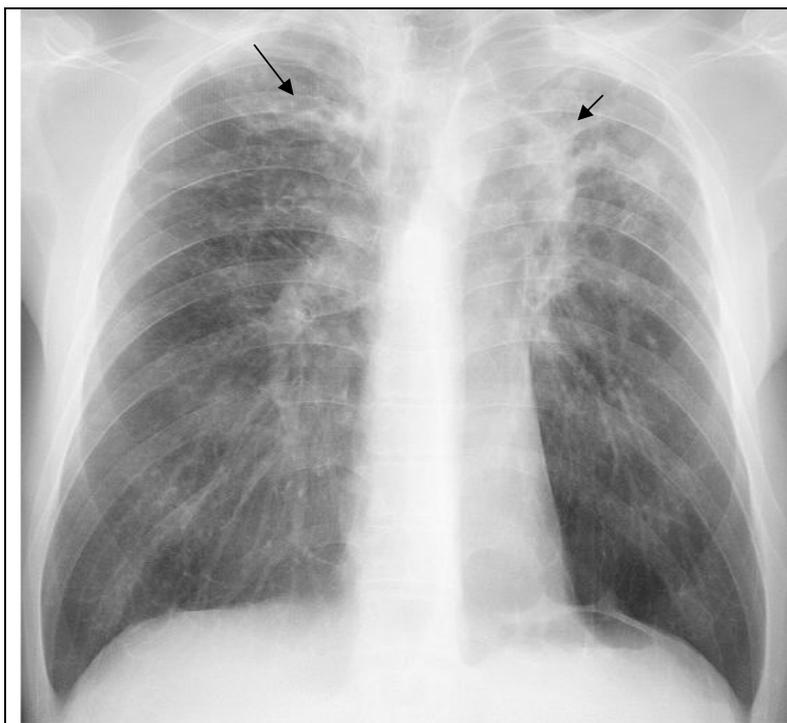


Fig. 6.50. The frontal chest radiograph. In the upper departments of both lungs the limited non-homogeneous shadows with distinct contours (arrow). Hilums of both lungs shift upwards. The tuberculosis of both lungs with fibrosis.

The computer tomography supplements data radiography and a longitudinal tomography at the expense of higher sensitivity to nodular changes and cavities of destruction. CT helps to distinguish the tubercular defeats of lungs hidden pleural effusion or massive pleural imposition.

The pneumoconioses (black-lung disease).

Black-lung disease refers to professional dust fibrosis of lung, developing at inhalation and accumulation in pulmonary parenchyma of an inorganic mineral, metal or organic dust. These include silica, asbestos, talc, berilium. Depending on character of development of pathological process and its distribution, distinguish interstitial, nodular and central forms pneumofibrosis. Disease usually proceeds years, steadily progressing. Alongside with development of a connecting tissue gradually there are emphysema sites (fig. 6.51).



Fig. 6.51. The frontal chest radiograph. Intensification of the interstitial marking. Plural nodular shadows mainly in the middle departments of lungs (arrow). Pneumoconiosis (silicosis).

6.10. Radiological signs of traumatic lung injuries.

At some patients they can be revealed already at first radiological examination, however traumatic changes in lungs can be detected at increasing hypoxia in 6-12-24 hours after a trauma. The most common type of injury is parenchyma rupture with haemorrhage around the affected part.

Pneumothorax can develop at thoracic trauma. The congestion of gas in the pleural cavity leads to partial collapse of the lung (passive atelectasis). Increased transparency of external departments of pulmonary fields and absence of lung pattern is typical; thus the density of the shadow of the collapsed lung increases. When both air and liquid are present in the pleural cavity simultaneously, roentgenoscopy or radiography should be performed (if the patient's condition is satisfactory for it) in the standing position or in the lateroposition. The established horizontal level of fluid enables to diagnose. At massive pneumothorax shift of the median shadow towards the healthy side can be detected on the radiograph (fig. 6.53).

Opacity of the pulmonary field serves as radiological symptom of traumatic injury of pulmonary parenchyma. Nodular shadows appear on the radiograph, which merge and usually localize in the basal or hilar departments of pulmonary field. Fast augmentation is typical for traumatic changes in lungs.

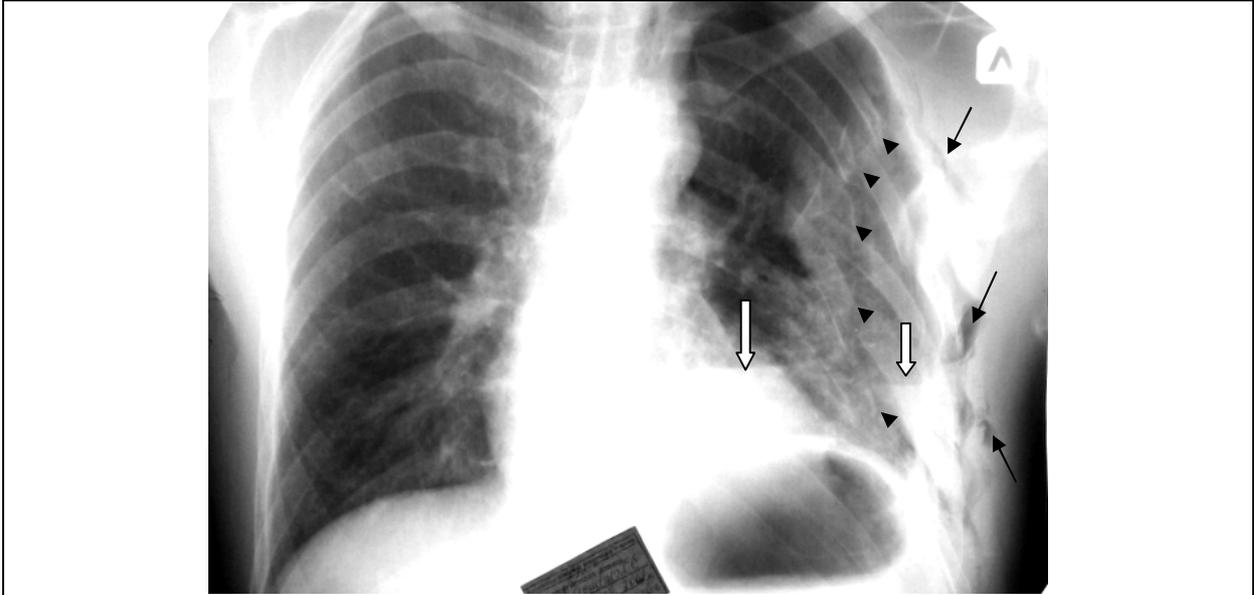


Fig. 6.52. Lines of fractures in back departments IV–VIII of ribs at the left (small black arrows). A non-homogeneous shadow in the left pulmonary field – average intensity in lateral and an average zone, high intensity in the bottom department with horizontal level (figured arrows). Radiolucent zones in a projection of soft tissue at the left (black arrows). The cupula of diaphragm at the left is raised. A bruise and rupture of the left lung, pneumothorax and hydrothorax at the left. Multiple fractures of ribs at the left (IV–VIII). Hypodermic emphysema.

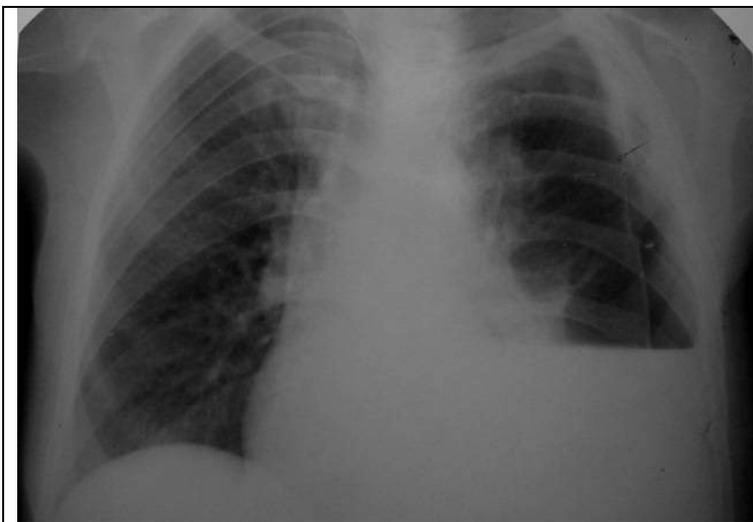


Fig. 6.53. The frontal chest radiograph. In the lower department of the right pulmonary field intensive homogeneous shadow with distinct horizontal top level. In lateral part of the left pulmonary field a radiolucent zone without elements of pulmonary vessels. The left lung in passive atelectasis (arrow). Mediastinum is displaced to the right. Pneumothorax and hydrothorax on the left.

The pneumonia on this background arises, as a rule, not earlier than 3-5 day after a trauma, occurrence new shadows.

The computed tomography plays an important role in detecting traumatic damages of chest wall, pleura and lungs. CT is more sensitive in detecting small traumatic damages of the lungs that are difficult to reveal on roentgenograms. By

means of CT even small congestions of fluid and air in pleural cavity can be detected. The liquid and gas can move on pleural space, and their revealing at radiography in position of the patient on the back is not always possible. Imaging on CT does not depend greatly on the patient's position, thus detectability of injuries increases.

6.11. Radiological signs of lung tumours

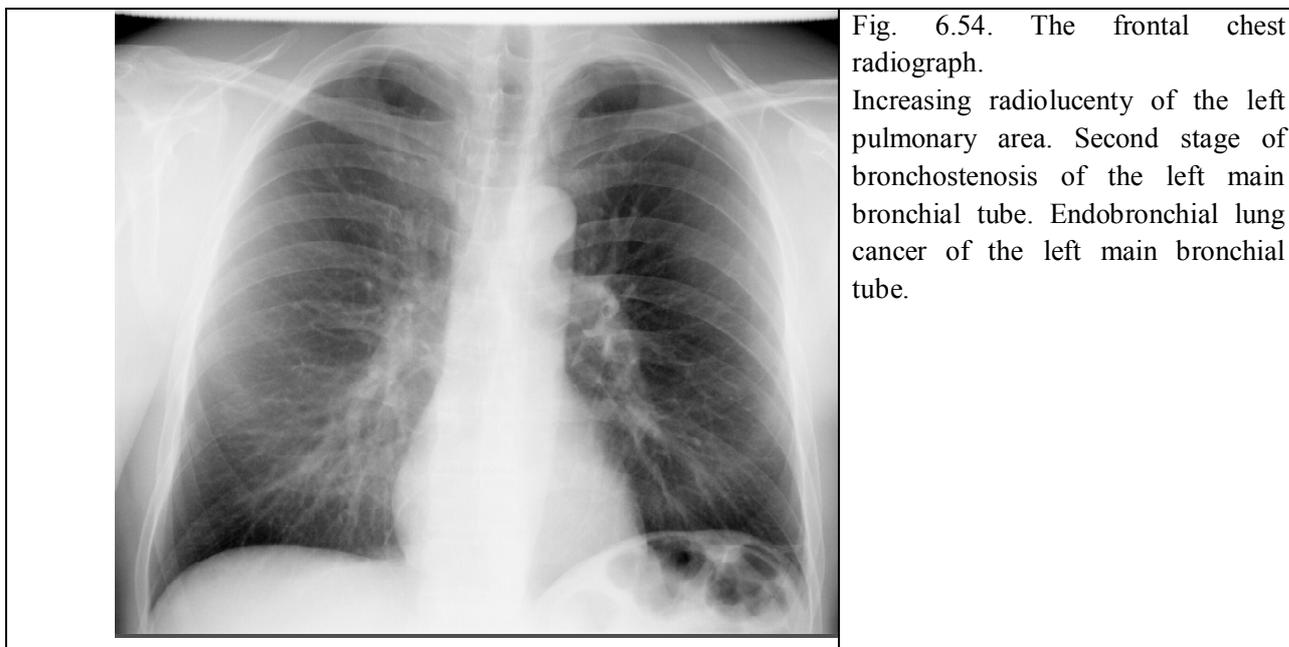
Lung cancer, (also called bronchogenic carcinoma) is the most common fatal malignant neoplasm. The radiological manifestation of lung cancer depends on the location of the tumour, its spread in the thorax and its histological type. Lung cancer invades locally by endobronchial and transbronchial growth, spreads within the lymphatic system to hilar and mediastinal nodes, and also spreads through the bloodstream to secondary sites, including other thoracic structures. When the tumour is peripheral, it presents radiographically as a solitary pulmonary nodule or mass. The cardinal signs of central tumours are lung collapse or obstructive pneumonitis of the lung beyond the tumour and the presence of a hilar or parahilar mass, signs which may be seen in isolation or in conjunction with one another. CT, because of its better contrast resolution, will detect smaller lesions and virtually eliminate the problem of the tumour being hidden by normal overlying structures. Both CT and MRI play a major role in lung cancer staging. Signs of intrathoracic spread include bone destruction, pleural effusion, hilar and mediastinal lymphadenopathy, metastasis in the contralateral lung.

The central lung cancer. Clinical symptoms of the disease are: bronchial passableness disorders, change of drainage function of the bronchial tube. Basically, complaints of the patient are reduced to cough, often attack-like one, discharge of phlegm with blood, short wind, general weakness, rise of body temperature up to subfebrile figures, loss of body weight.

Central cancer develops from epithelium of the mucous membrane of large bronchial tubes: main, lobe or segmentary. Growth of a tumour can be directed to a lumen of the bronchial tube (mainly endobronchial cancer), peribronchial growth of a tumour outside from a wall of the bronchial tube (mainly exobronchial a cancer) is rather seldom observed.

In endobronchial of cancer tumour growth in an initial phase of development when the sizes of a tumour are very small, it is impossible to establish the diagnosis clinically and radiologically. In case of increase of its sizes ventilation of the lung segment or lobe is damaged, what gives the basis to suspect a tumour. There comes

the second phase of tumour development and the first stage of bronchostenosis development - hypoventilation. At the second bronchostenosis stage valvular emphysema can develop which is characterized by the increased transparency of a segment or a lobe, expansion of intercostal intervals, displacement mediastinum at the forced breath in the healthy side (fig. 6.54).



In process of tumour growth obturation of bronchus (bronchial passableness disorder of the third stage) occurs what causes development of bronchostenosis. In radiological research find the atelectasis of a segment, lobe or lung look like a homogeneous intensive shadow, with reduced sizes, concave interlobar borders, high located diaphragm and mediastinum displaced to the side of the lesion (fig. 6.55).

Bronchography detects pulmonary filling defect; in initial stages – rough, wavy contour, amputation of the bronchial tube in total obturation.

Tomograms help to detect narrowing of the bronchial tube lumen, a tumour shadow or bronchus air column rupture in its obstruction by the tumor.

Cancer growth outside the bronchial tube. Changes occur in the hilar zone, its expansion is detected due to primary tumour and MTS in lymph nodes, the shadow of the root loses its structure, merging with a median shadow. The contour is inverted to the pulmonary field, it is radiant and laminate, what testifies germination of the tumour in surrounding pulmonary tissue. The increase in tumour sizes up to several centimeters in diameter results in narrowing of the bronchial tube lumen, and ventilation disorders. Mainly peribronchial growth of a tumour to define it is not

possible, as from the very beginning of occurrence it attachment a course of a bronchial tube and vessels.



Fig. 6.55. Frontal and lateral chest radiographs.

In upper department of right pulmonary field homogeneous shadow with lower concave contour (arrows) and without air bronchogram.

Right upper lobe consolidation and atelectasis caused by endobronchial lung cancer.

In process of growth of a tumour are formed thickening around of bronchial tube and on chest radiograph the rough shadows fanlike departing from a root in lung parenchyma are defined.

On tomograms the homogenous thickening of walls of bronchial tubes is defined. At the further growth of the tumour and germination of the wall bronchial lumens are narrowed, hypoventilation occurs. Bronchography detects extended concentric narrowing of the bronchial tubes and their walls thickening (fig. 6.56 and 6.57).



Fig. 6.56. Chest film. Limited shadow in the hilar zone of right lung with indistinct contours. Central cancer of the upper lobe of right lung when the tumor grows to outside from a bronchial tube.

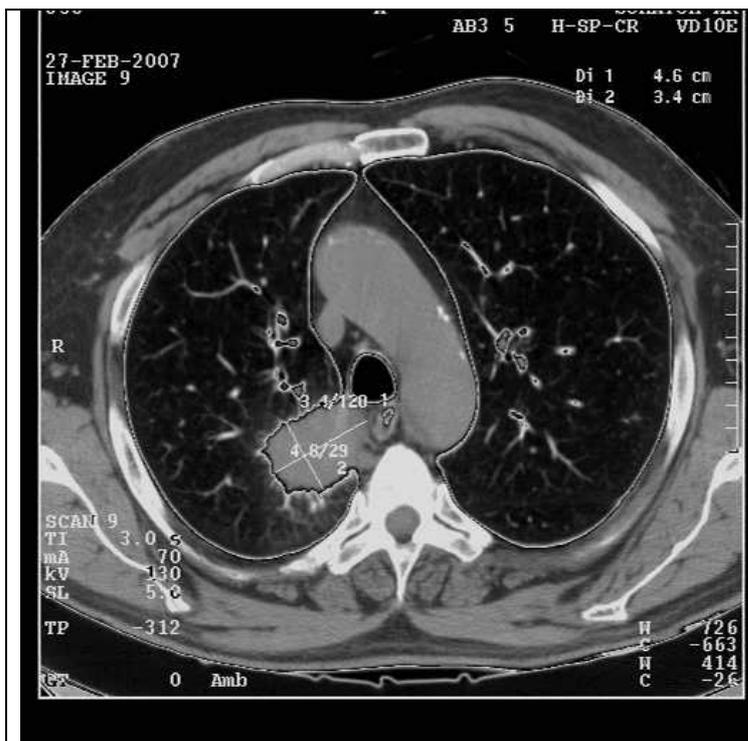


Fig. 6.57. Ct-scan on the level of arch of the aorta. In the area of right hilum there is a shadow with irregular contour. Central cancer of the upper lobe of the left lung when the tumor grows outside the bronchial tube.

Peripheral lung cancer develops from the small bronchial tube wall and more often grows as a node, locating under the pleura, or on significant distance from the pleura. The most often peripheral cancer localization is detected in the right lung and the upper lobes of both lungs.

Clinically, peripheral cancer does not manifest itself for a long time as it is located far from major bronchi. In this connection, it is more often detected radiographically. Clinical manifestations arise later and are characterized by occurrence of chest pain what is caused by germination of tumour in the pleura, in its germination in the bronchial tube cough with phlegm and hemoptysis occur. Peripheral cancer in the beginning of its development forms small nodes of the polygonal form with diameter of 3-4 cm; it acquires the spherical form. Growth of the tumour can be slow or fast. Shadow ntensity can be various depending on the node size. The shadow is more often non-homogenous, contour is irregular (hilly, bumpy).

Pulmonary pattern close to the tumour node is usually deformed, what is likely caused by previous chronic inflammatory process. In some cases it is possible to see the path going from a round shadow of the tumour to the root of the lung, caused by lymphangitis or peribronchial and perivascularis tumour growth (fig. 6.58).

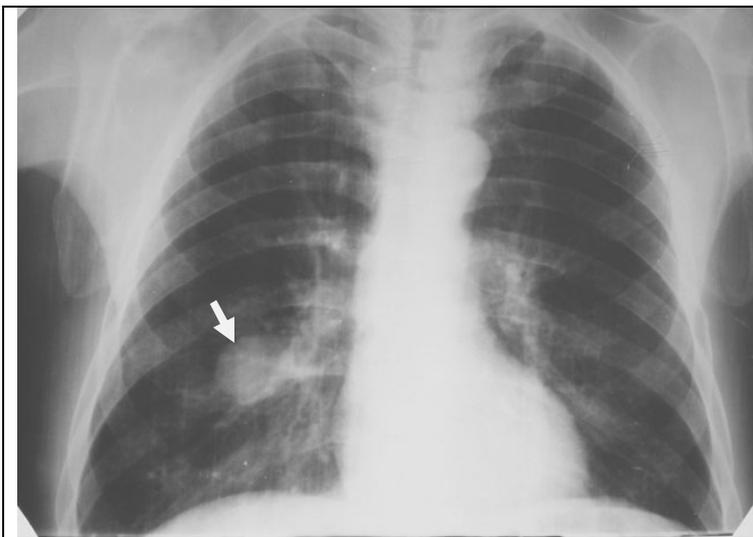


Fig. 6.58. Chest film. A round a shadow in pulmonary a field (arrow). Peripheral lung cancer.

The tomography performed in peripheral cancer detects knottiness of the tumour shadow, the cavity of disintegration; it helps to reveal drainage of the bronchial tube, a condition of lung root and mediastinum lymph nodes (fig. 6.59).



Fig. 6.59. Ct-scan on the level of the aorta arch. Round shadow with a radiant contour in the second segment of the right lung (arrow) is detected. Peripheral lung cancer.

Lung apex cancer (Pancoast's neoplasm). Clinical manifestation is late. Pains are typical. Radiographically this cancer is characterized by a shadow which occupies the area of the whole lung apex. The bottom border of the shadow is distinct and is inverted by camber downwards while other borders are not differentiated. On the shadow background usually it is possible to see the destruction of posterior rib parts and several vertebrae (fig. 6.60).

Mediastinal form of cancer. In the clinical picture the most important is compression syndrome (vena cava superior, large nervous trunks). Such symptoms as neck and face edema, feeling of compression in the neck and chest area are observed. Primary localization of a tumour in most cases appears not clear, the minimal sizes of a tumour do not allow to define it at radiological research, the early tendency to metastasis in lymph nodes mediastinum however is characteristic.

Nowadays the leading way of mediastinum lumps diagnostics is CT and MRI which allow to establish exact localization of a lump, its relations with surrounding anatomic structures, and in some cases to give enough exact tissue characteristic of a lump (lipoma, cyst).

Radiographically the picture, characteristic for a mediastinum tumour is: presence of the extensive tissue overlapping a shadow of the lung root from the one side (increase lymph nodes unilateral), merging with a median shadow. Sometimes it is difficult to define the nature of the increased lymph nodes because Hodgkin's disease or lymphosarcoma can give a similar picture (fig. 6.61).



Fig. 6.60. CT slices on the level of Th_{III} vertebra.
 Mass in upper lobe of left lung, which involves Th_{III} vertebra, soft tissue and back part of the IV rib (arrows).
 Pancoast's neoplasm of the left lung.

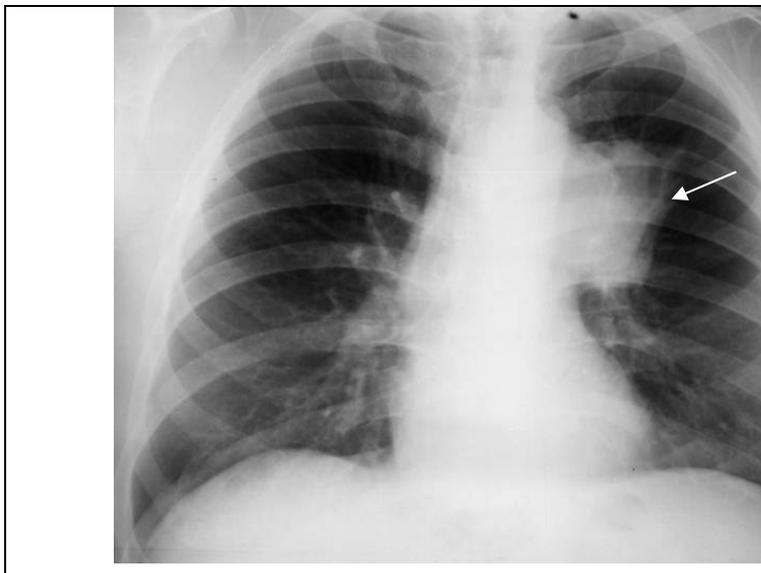


Fig. 6.61. The frontal chest radiograph.
 Conglomerate of the increased lymph nodes in the hilum of the left lung (arrow).
 Mediastinal form of lung cancer in the left side.

MTS in lung.

As a rule, MTS give a round shadow in the x-ray image. They are usually multiple, but sometimes solitary MTS can be observed. CT is the most sensitive method of detection of MTS in lungs. It provides confident identification of small

nodes with the size up to 3 mm (radiographically > 6 mm); in the area of lung roots a threshold of revealing for CT is 5-6 mm (fig. 6.62 and 6.63).

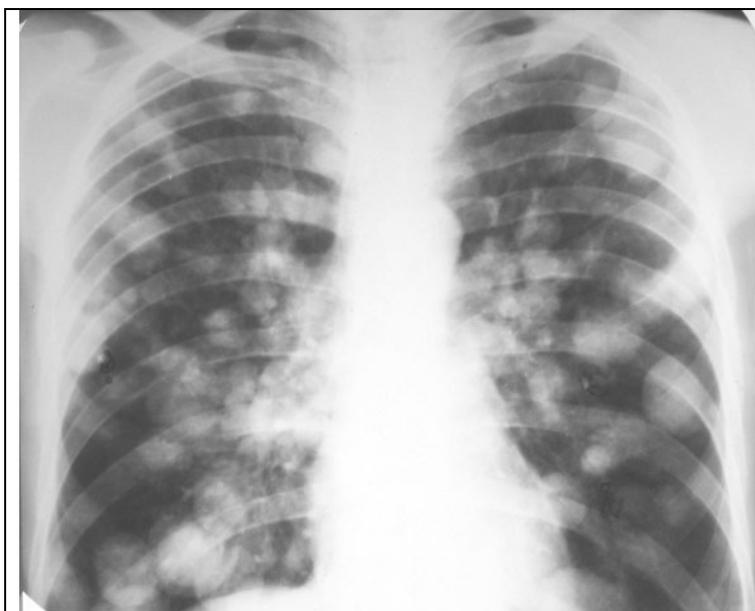


Fig. 6.62. Chest film.
Multiple round shadows in both lungs.
Cancer metastases in lungs.

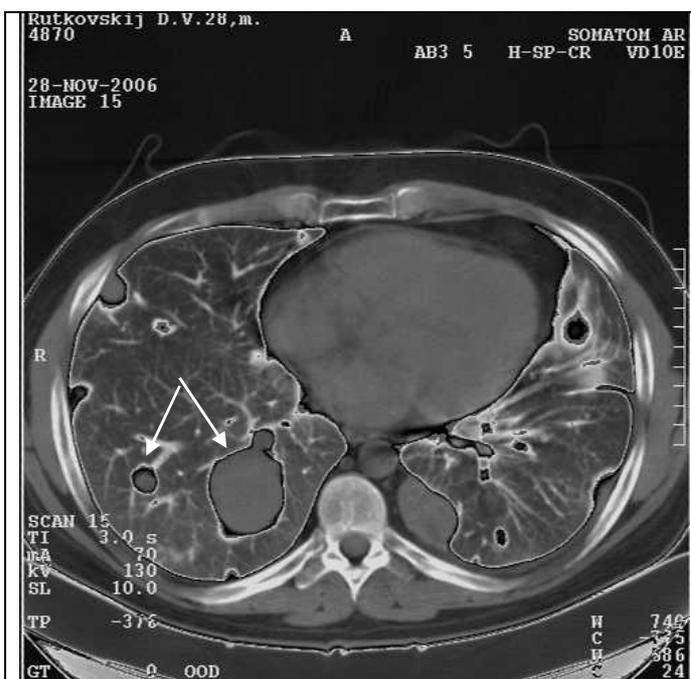


Fig. 6.63. The computer tomogram of the thorax at level T_{IX}. Multiple cancer metastases in both lungs. (some metastases are specified by arrows).

Miliary carcinomatosis. Miliary carcinomatosis manifests itself as small-focalsymmetric dessimination, especially dense in the inferior parts of lungs.

The differential diagnosis is difficult. It is necessary to carry out careful phlegm analysis and puncture biopsy.

CAPTER 7. CARDIAC IMAGING

Cardiovascular diseases and their complications are the leading reason of death rate in all industrially-developed countries. Modern technologies of cardiovascular pathology treatment are closely connected with radiodiagnostics. In patients with heart and vessels diseases the following radiological methods of research are used:

1. Primary methods:

- fluoroscopy and radiography in standard projections;
- echocardiography and doppler echocardiography.

2. Additional methods (noninvasive):

- CT;
- MRI;
- scintigraphy, SPET or PET

3. Additional methods (invasive):

- ventriculography;
- angiography.

To improve imaging echocardiography, CT and MRI with intravenous introduction of contrast agents can be used.

7.1. Technical considerations

Radiography is a standard screening examination in patients with suspected cardiac disease. Knowing the normal anatomy portrayed on the anterior-posterior (posterior-anterior) and lateral films and by analyzing the sizes of pulmonary arteries and veins, it is possible to make a correct diagnosis in the majority of cases.

Radiography of the thorax in standard projections: direct, left lateral, left and right forward oblique projections remain a widespread research till nowadays thanks to following possibilities:

- estimation of pulmonary haemodynamics condition;
- detection of heart configuration sizes;
- revealing of calcification structures on the heart and vessels walls;
- exception of other organs pathology simulating clinical semiology of heart and vessels diseases.

Complex use of radiography and ultrasound research allows to do without oblique and lateral projections in most cases. Additional radiographs in oblique projections are required only in 15 % of cases.

The cardiac series is a four-view examination consisting of PA, lateral, and right anterior oblique (RAO) views with the patient drinking barium, and a left anterior oblique (LAO) view without barium. Barium is used to determine whether or not specific chamber enlargement impinges on the esophagus. The LAO view does not use barium since that substance would obscure the aortopulmonary window.

For appreciation of the anatomic relationships of the heart and its chambers, it is necessary to think in three-dimensional terms. Let us examine the position of the cardiac chambers, the great vessels, and the aortic and mitral valves as seen in the four-view cardiac series.

The chest (heart) radiograph in a direct projection. In a direct projection on the right contour there are two arches. Bottom is formed by the right atrium; top an ascending aorta (sometimes vena cava superior). Between arches there is an angle named right atriovascular angle. The left contour of the cardiovascular shadow is displayed as four arches. Top is formed by a shadow of the arch and the beginning of the descending aorta part. The second from above arch is a trunk and the left branch is the pulmonary artery, (nonconstantly) the arch the left atrium below settles down.

Left ventricle arch closes the left contour of the heart. The angle between the arch the left atrium and an arch pulmonary artery refers to the left atriovascular angle. The distance from the left ventricle arch up to left medial clavicle lines should make not less than 1,5-2 cm, and from the average line up to the most protrudent point of

the upper arch of the left contour - 3-4 cm. The upper contour of the cardiovascular shadow will be in a distance from the horizontal line connecting breast bone-clavicle joints, on 1,5-2 cm. Lengths of arches of the pulmonary artery trunk and the left auricle should be about 2 cm each one. Structure of the normal heart shadow and large vessels is usually homogeneous, without additional inclusions (fig.7.1).

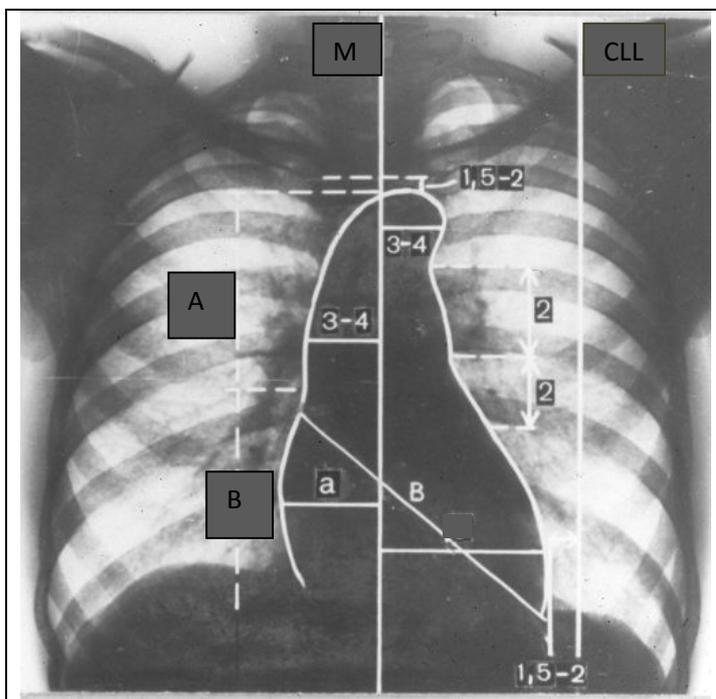


Fig. 7.1. The chart of radiograph of a chest. The sizes of heart arches are specified. M is the median line. CL is the half-clavicular line. A is ascending aorta. B is right auricle.

In the normal lateral view, the anterior border of the cardiac silhouette consists of the right ventricle. The posterior and inferior cardiac border is that of the left ventricle. The image of the inferior vena cava superimposes on the posteroinferior border of the left ventricle, occasionally extending just posterior to the left ventricular outline. The left atrium forms the superoposterior border of the heart. The barium-filled esophagus courses almost immediately posterior to the cardiac silhouette. It should not be indented by the heart under normal circumstances. Occasionally, the image of the pulmonary artery may be observed arching up from the right ventricle and passing inferiorly to the arch of the aorta, which is also visible on the lateral film (fig. 7.2).

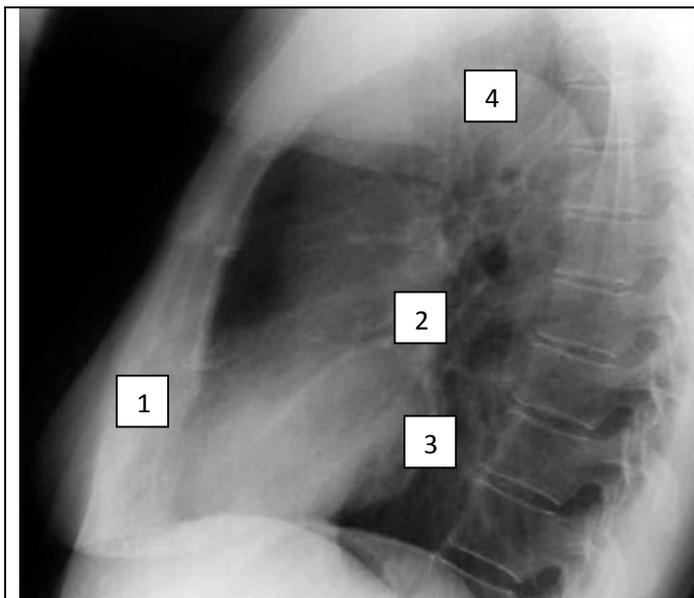


Fig. 7.2. The chest radiograph in the left lateral projection. 1 – the right ventriculus, 2 - the left atrium, 3 - left ventriculus, 4 - the aorta arch

The increase in atrium sizes leads to the esophagus displacement. The dislocation can occur on the arch of the big and small radii. The arch of the big radius is more, and small is less than 6 cm (fig.7.3). In the second oblique projection (under a corner 45° to the screen the left side) heart and vessels also have two contours – forward and back. The anterior contour is formed from below by the right ventricle; the arch of the right atrium is above. The uppermost arch is formed by the ascending aorta. A posterior contour consists of: from below – the arch of the left ventricle, from above – an arch of the left atrium (fig. 7.4).

The form of the heart and large vessels. The normal form of heart is characterized by well enough expressed arches, forming a contour of the heart and large vessels. The shadow of heart is oblique and also has the normal sizes.

Mitral form of the heart is allocated with the following features. The length and chamber of the arches is formed by a trunk and the left atrium increase. Left atriovascular angle decreases and right atriovascular angle is displaced upwards (fig. 7.5).

Aortical form. The following signs are characteristic:

1. Emphaticalness of the waist (expressiveness, dredging on the left contour between the aorta arch and the left ventricle arch, therefore the distance between atriovascular corners seems small).

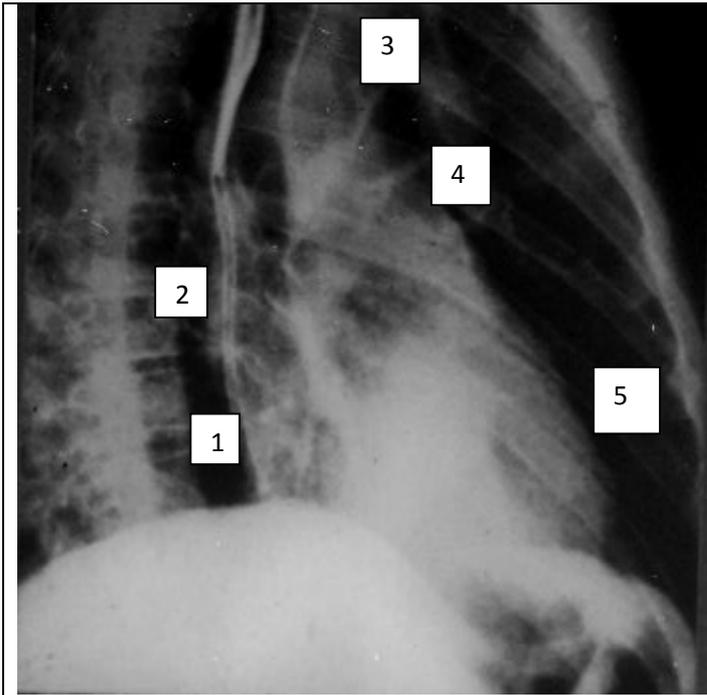


Fig. 7.3. The heart radiograph in the right (first) slanting projection. The contrasted oesophagus settles down rectilinearly. 1-arches of the right atrium, 2-arch of the left atrium, 3-arch of an ascending aorta, 4-arch of the pulmonary cone, 5- left ventriculus arch.

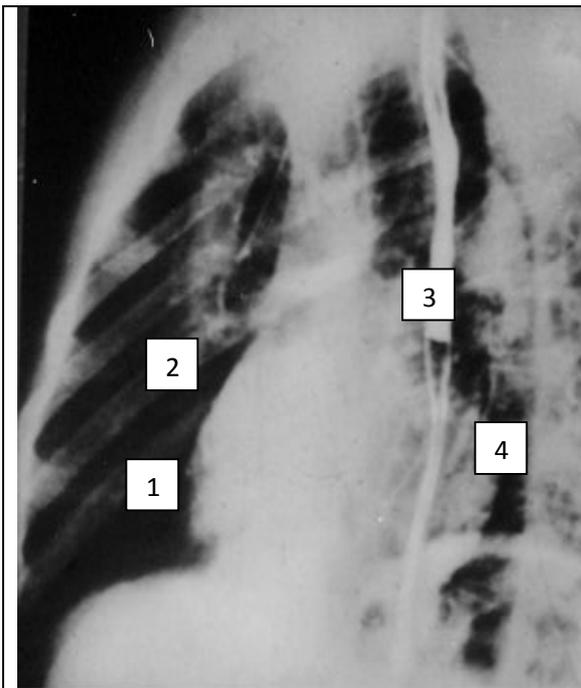


Fig. 7.4. The heart radiograph in the left (second) slanting projection. 1- right ventriculus arch, 2-arch of the right atrium, a 3-arch of the left atrium, 4-arch of the left ventriculus.

2. Increase of the arch forming the left ventricle.
3. Lengthening of the arch and expansion of the shadow in the projection of ascending aorta (the right contour, the top arch).

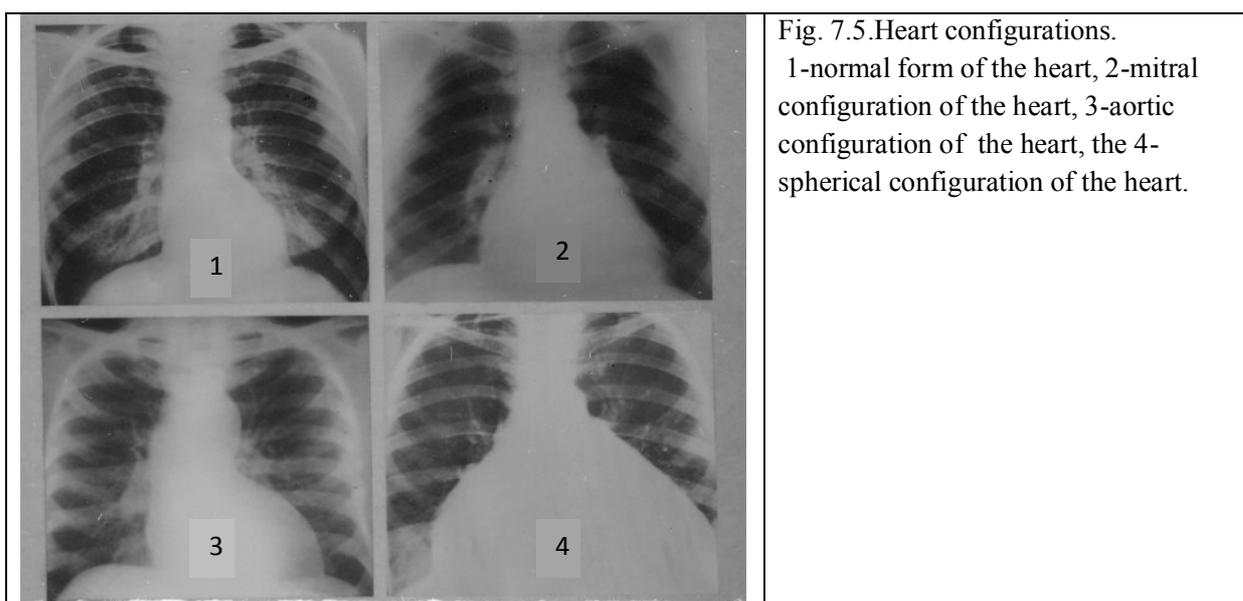
4. Lengthening the top arch of the left contour is conditioned by the arch and the descending part of the aorta.

5. Displacement downwards of the right atriovascular angle.

At the triangular form of heart its sizes are in regular intervals increased and division of contours into arches is not observed. In a direct projection the form of the heart shadow and large vessels has similarity with triangle or a trapeze.

A popular method used to determine cardiac size is the cardiothoracic ratio: the maximum width of the cardiac shadow on the posterior-anterior (PA) or anterior-posterior (AP) chest film divided by the maximum width of the thorax (norm is $< 0,5$).

Fluoroscopic examination of the heart and pulmonary vessels is used for epy assessment of cardiac motion, contour, and dynamics (useful for evaluation of cardiac aneurysms), (b) investigation of intracardiac calcifications (valvular, coronary artery, or pericardial), and (c) assessment of patients with suspected pericardial effusion (dampened pulsations).



It has largely been replaced by echocardiography. Cardiac catheterization and coronary arteriography are invasive procedures performed almost exclusively by cardiologists or cardiovascular radiologists. These procedures allow accurate evaluation of the size and configuration of the cardiac chambers, the great vessels, and the coronary arteries. They are also performed to evaluate patients with suspected shunt lesions.

Computerized tomography, performed with electrocardiographic CT gating, is

used with contrast enhancement for a variety of cardiac conditions. In this technique, dynamic scanning –multiple images of one section – is performed to evaluate flow through a particular chamber or vessel. In addition, CT is used to evaluate the patency of coronary artery bypass grafts, to assess the extent of myocardial infarcts, to depict the size and location of left ventricular aneurysms, to detect aneurysms of the thoracic aorta, to diagnose aortic dissections, to define certain congenital abnormalities such as coarctation of the aorta and anomalous venous connections, and to assess the pericardium for effusions (fig. 7.6).



Fig. 7.6. The computer tomogram of the chest. Calcification of the pericardium is detected. (arrows).

Dynamic CT is also used for determining myocardial wall thickness and dynamics, although echocardiography is used much more commonly.

Modern technology CT provides three-dimensional reconstruction of the vascular tree. CT-angiography becomes in some cases alternative to angiography as a definitive method of stenosis and aneurysm diagnostics. Unlike angiography this method allows to visualise not only the vessel lumen, but also a clot of blood with surrounding tissue. Spatial resolution of CT-angiography is lower, than that of angiography. One of indications for CT - angiography is visualisation of the trunk veins in thrombosis, occlusion, anomalies of development, tumours (fig. 7.7, 7.8, 7.9).



Fig. 7.7. CT with contrast enhanced. The forward descending coronary artery with calcification (arrow) is visualised.

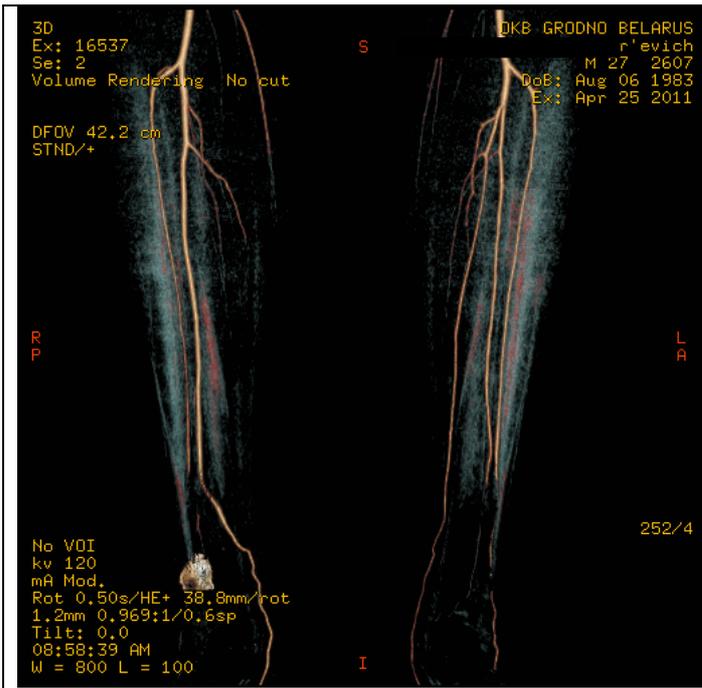


Fig. 7.8. 3 D spiral CT. Occlusion of the right fibularis artery.

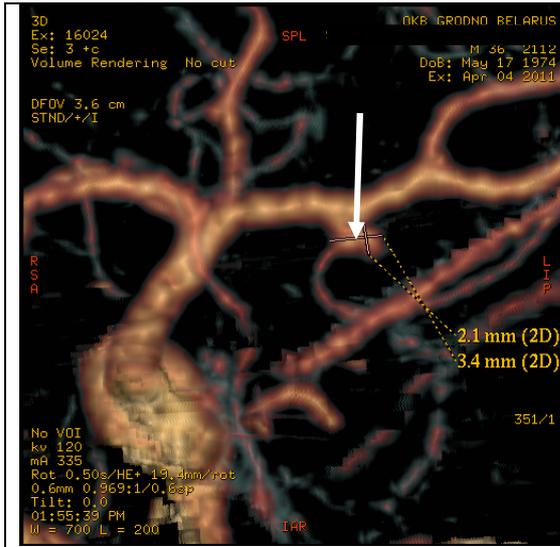


Fig. 7.9. 3 D spiral CT. Aneurism at posterior brain artery (arrow).

Angiocardiography may be performed from either the right or the left side of the heart. In venous angiocardiography the catheter tip was sited either in the superior or inferior vena cava, and a bolus of contrast medium injected at high pressure. Rapid films were taken demonstrating its passage through the various chambers of the heart.

Right heart angiocardiography is now more usually performed by siting the catheter tip in the right atrium. In many congenital heart conditions selective angiocardiography is performed with the catheter tip sited in the right ventricle or pulmonary outflow tract (fig. 7.10).



Fig. 7.10. Digital right angiocardiography in a direct projection. Phase of contrasting of pulmonary arteries

The left side of the heart can also be shown by following the contrast agent through the lungs to the left auricle and ventricle on serial films. However contrast values are not as good as in direct left heart ventriculography.

For left heart angiocardiology the catheter tip is sited in the left ventricle by the method of transfemoral catheterisation just described. Injections are made through the catheter and rapid serial films taken. The left ventricle is best studied by video-filming, and this method is essential in the study of the ischaemic heart in coronary disease. Left ventricular function is assessed radiologically by noting the adequacy of left ventricular contraction and the presence of dyskinesia areas. Mitral incompetence can be demonstrated at left ventriculography by opacification of the left auricle and the degree of incompetence quantified.

The aortic valves may be studied by injections made into the root of the aorta. With aortic incompetence there will be regurgitation into the left ventricle; with aortic stenosis the narrowed jet of blood from the ventricle will be shown as a defect in the opacified aorta.

Echocardiography. The cardiac series, too, has largely been replaced by echocardiography. Real-time echocardiography has decreased the number of catheterizations used to determine cardiac chamber size and configuration.

Echocardiography, cardiac imaging technique based upon the velocity of sound travelling through and reflected from acoustic interfaces in cardiovascular structures. It has progressively evolved from M-mode echocardiography to the current multifaceted capabilities including transthoracic and transoesophageal echocardiography, three-dimensional echocardiography, Doppler velocity measurement, colour flow mapping and intravascular imaging. Echocardiography has become the most frequently performed diagnostic study for cardiac diseases. Echocardiography is the most widespread beam method of research of heart and vessels, thanks to the availability and information. Combination echocardiography and doppler echocardiography allows to estimate:

- a status of departments of heart and large vessels;
- a status of intracardiac structures;
- intracardiac and central haemodynamics;
- total and segmentary myocardium contraction function;
- presence of pathological intracardiac shunts;

Transoesophageal echocardiography requires passage of an oesophagoscope with an ultrasound transducer at its tip which can be angled and placed at different levels

behind the heart. This enables high quality images to be obtained in cases where the conventional techniques are difficult or unsuccessful.

M-mode echocardiography provides a one-dimensional (distance from the transducer versus time) view of cardiac structures. Cardiac motion is displayed as a change in position of cardiac structures; i.e. mitral leaflet motion, over the cardiac cycle. The distance between and changes in distance between various cardiac structures is displayed on one-dimensional echocardiograms. The M-mode method provides interrogation of moving cardiac structures with a sampling rate of nearly 1000 cycles/sec. The M-mode echocardiogram also depicts abnormal patterns or velocity of motion in cardiac structures such as the mitral leaflet in flail mitral valve and mitral stenosis, respectively.

Two-dimensional echocardiography (2DE) uses rapid movement of the one-dimensional ultrasonic beam across the heart to provide real-time cross-sectional images. It is the standard ultrasound imaging method for the heart. There are two major types of two-dimensional imaging devices, mechanically driven large crystals and electronically driven phased crystal arrays. The electronically driven systems are now dominant.

Doppler echocardiography allows the measurement of intracardiac and intravascular flow velocities by detecting changes in the frequency of reflected ultrasound emitted by and then returned to the transducer. After emitted ultrasound strikes moving red blood cells, the frequency of the ultrasound is shifted in proportion to the velocity of the cells. This velocity difference of the ultrasound is displayed as a function of time and direction of the flow in relation to the transducer. There are two types of Doppler modalities: pulse wave Doppler and continuous wave Doppler. Pulse wave Doppler is capable only of measuring velocities accurately in the lower range due to aliasing. Flow mapping or colour Doppler is a special form of pulsed wave Doppler. Colour Doppler is used to screen the heart for flow disturbances such as valvular regurgitation and stenosis. Continuous wave Doppler obviates aliasing and can be used to accurately measure high velocity flows such as those associated with stenoses.

Ultrasonic anatomy of heart. At heart research standard positions of the transducer (fig. 7.11, 7.12, 7.13) are used:

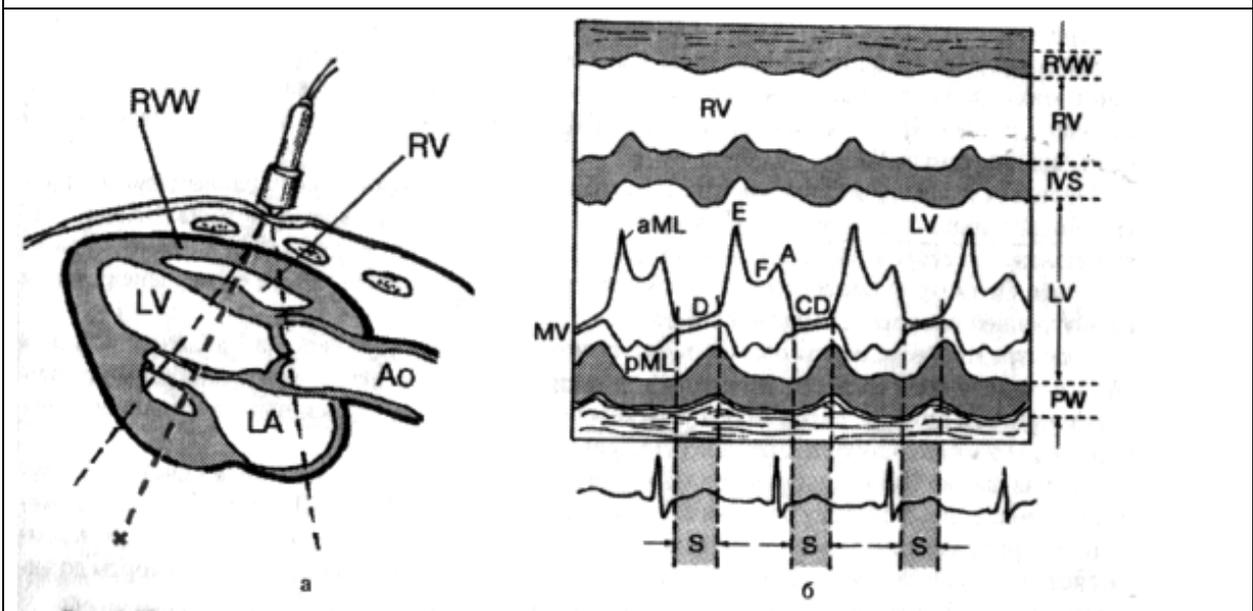
- 1 Parasternal position – area between the III-V ribs to the left from the breast.
2. Apex position – area of the cardiac top shove.
3. Subcostal position – area under processus xiphoideus.
4. Suprasternal position – fossa jugularis.

Overall, the most common indications for echocardiography are suspected chamber enlargement, congenital heart disease, abnormalities of heart valves, abnormalities of contractility, and suspected pericardial effusions. This examination is performed primarily by cardiologists.

Cardiac magnetic resonance imaging, noninvasive cardiac imaging technique in which intrinsic contrast exists between the blood pool and cardiac structures. There are several features which are useful for cardiac imaging. High contrast between the blood and cardiac structures exists because of the low or absent signal of flowing blood on spin echo images or the high signal of blood on gradient echo images (fig. 7.14).

A wide range of contrast among soft tissues provides the potential for myocardial tissue characterization. The capability to acquire tomograms in any plane allows images to be acquired along the long axis (parallel) or short axis (perpendicular) of cardiac chambers and other cardiovascular structures. It is essentially a three-dimensional imaging technique which provides the most accurate and reproducible measurements of cardiac volumes and myocardial mass. Flow-sensitive MR sequences provide spatially precise measurements of velocity and volume of blood flow in cardiac chambers and blood vessels. Magnetic resonance imaging is employed to diagnose many of the same abnormalities that can be seen with CT.

Fig. 7.11. Ultrasound examination (M-mode) from left parasternal position on the heart long axis. Position of a transducer ultrasonic beam is at the level of leaflets mitral valve.



RVW – forward wall right ventriculus. Behind it the cavity of right ventriculus

(RV) and septum interventriculare (IVS) is visible. LV – cavity of the left anterior (aML) and posterior (pML) leaflets of mitral valve move. PW – the back wall left ventriculus.

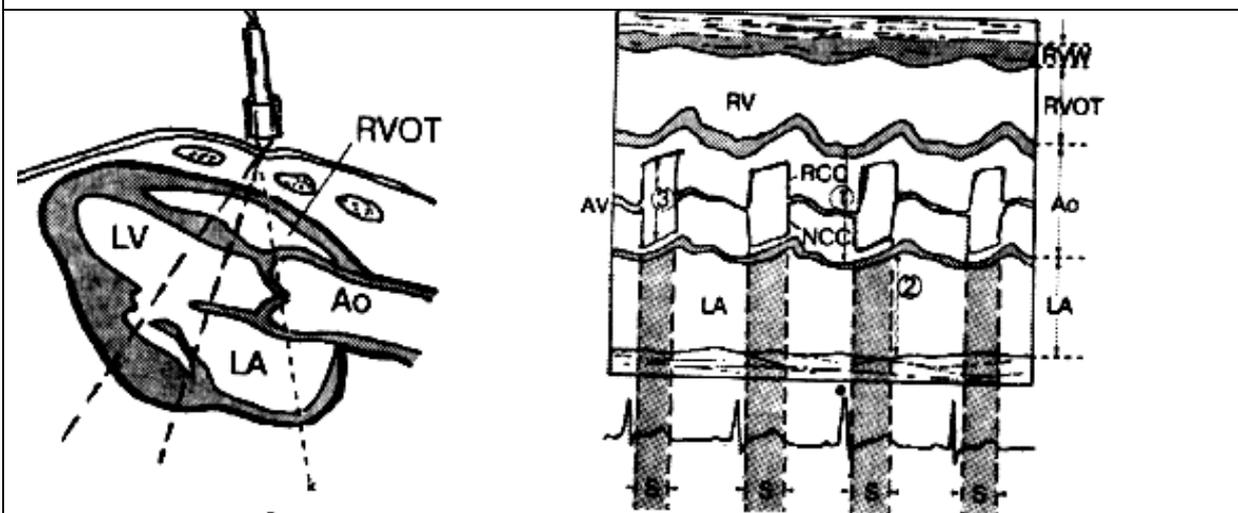
Normally in diastole diphasic M-shaped movement of aML and W-shaped movement pML is defined. On a curve of movement of aML some sites are allocated:

1. Interval C-D corresponds to systole LV and full closed valve leaflets.
2. Interval D-E reflects a divergence of leaflets of the valve during a phase of fast filling LV.
3. Interval E-F - incomplete cover of leaflets of the valve during a phase of slow filling.
4. The wave A is caused by a repeated divergence of leaflets during systole LA.

Electrocardiographic gating is used for "stop-action" images of the heart and great vessels. Magnetic resonance imaging has the advantage of portraying flowing blood as a signal void (black) so that it is easy to distinguish blood from solid structures. Magnetic resonance imaging is most useful for evaluating patients with aortic dissections and aortic coarctation as well as chamber abnormalities.

Myocardial metabolic imaging, techniques used clinically to assess myocardial viability with nuclear scanning techniques and in research to evaluate various metabolic pathways in the heart in vivo with nuclear scanning techniques and MR spectroscopy. The classical example is PET imaging with fluorodeoxyglucose (FDG). In this technique, a PET perfusion image is acquired first followed by images of myocardial FDG uptake.

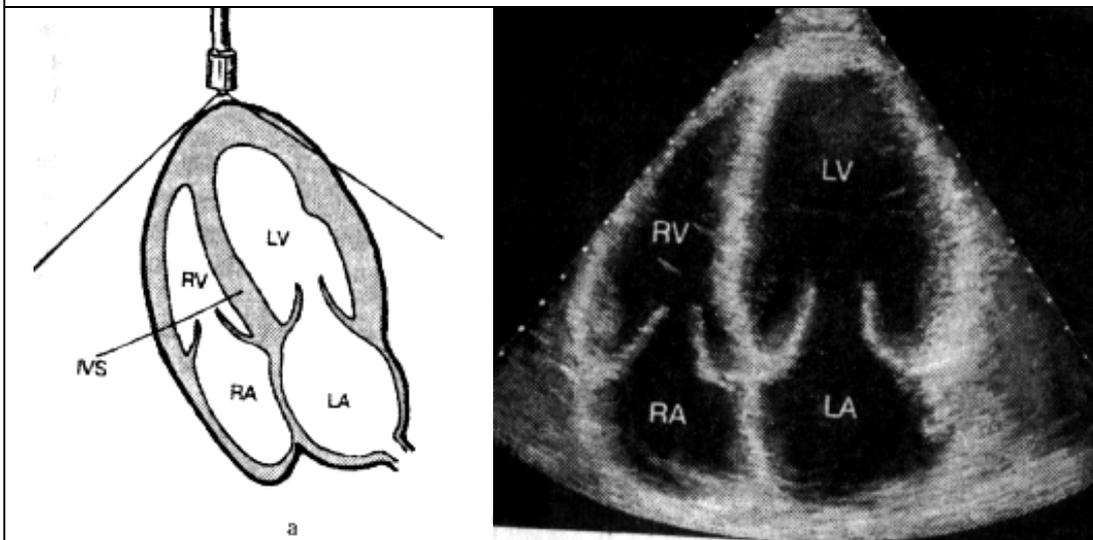
Fig. 7.12. Ultrasound examination (M-mode) from left parasternal position at the level of the aorta and aortic valve.



The note: S - systole ventriculus, RVOT - right ventricular outflow tract, RCC - right coronary leaflet aortic valve, NCC - not coronary leaflet aortic valve, «1» - diameter of the aorta, «2» - diameter LA, «3» - amplitude of disclosuring of the aortic valve.

Fig. 7.13. The scheme of ultrasonic scanning in apex positions of the four-chamber heart. Ultrasound examination (B-mode). Research from apex position.

The transducer is established precisely over the area of the heart top, focusing the central ultrasonic beam in longitudinal axis to the heart. Thus the scanning plane "dissects" heart along its long axis and passes through both atrioventriculus valves, fixing their full disclosing in diastola.



The note: septum interventriculare and septum interatriale partitions settle down in the centre. To the left of them right ventriculus (RV) and the right atrium (RA) are visualised and on the right - left ventriculus (LV) and left atrium (LA). In this position leaflets mitral and tricuspid valves are well visualised also. Anterior leaflet mitral valve (aML) is located closer to the medial line and the septum leaflet of the tricuspidalis valve, and lateral - a back leaflet mitral valve (pML) and a forward leaflet of the tricuspidalis valve.

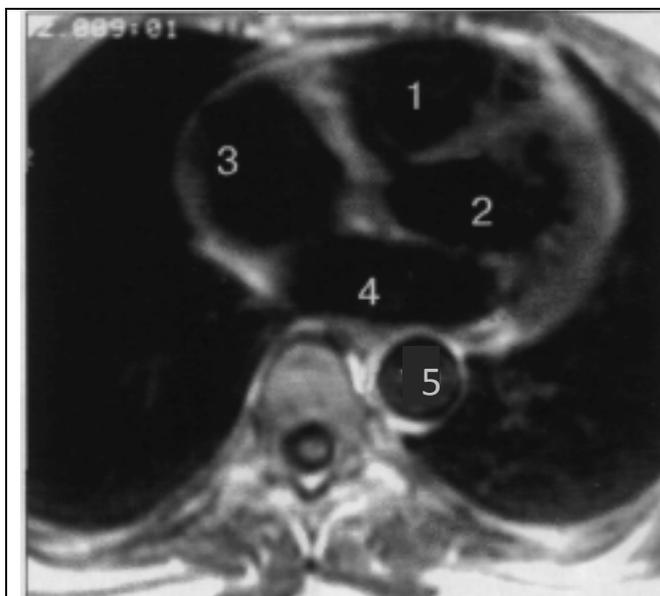


Fig. 7.14. MRI (T1 -WI) of the chest at the level of Th VII vertebra. 1 - right ventricle, 2 - left ventricle, 3- right atrium, 4 - left atrium, 5- descending aorta.

Areas which show persistent metabolism (FDG uptake) but poor perfusion are identified as hibernating myocardium. Thallium-201 (^{201}Tl) can also be used as a marker of myocardial vitality, as rest injection and imaging after at least 1 hour will

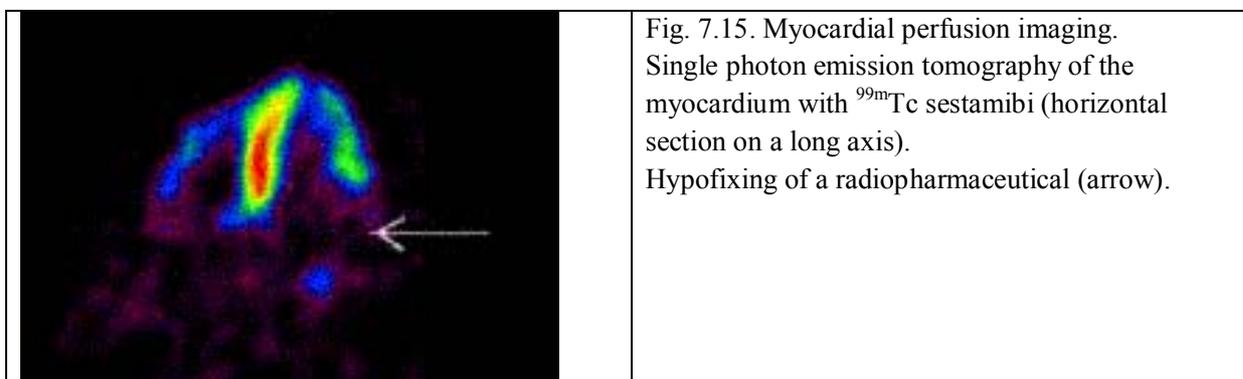
show regions of delayed uptake which are also identified as hibernating myocardium. PET imaging is considered the gold standard for this diagnosis while thallium is considerably less sensitive. An alternative method used to identify hibernating myocardium is stress echocardiography.

Nuclear myocardial perfusion imaging is the method for displaying the regional myocardial distribution of radiolabelled perfusion agents as an indicator of myocardial blood flow. Usually, the localization of the agent involves blood flow in capillaries, extraction from capillaries and retention in viable myocytes. Regional distribution of nuclear perfusion agents is influenced by two major factors: myocardial blood flow and myocardial cellular viability. Myocardial perfusion imaging is the most frequently employed method for the diagnosis and determination of the severity of ischaemic heart disease. The technique has evolved from planar imaging to single photon emission tomography (SPECT). The perfusion agents most frequently used are thallium-201 (^{201}Tl) and technetium-99m ($^{99\text{m}}\text{Tc}$) labelled agents. The initial distribution of ^{201}Tl is related to regional blood flow and the relative myocardial extraction of the tracer from the blood. The early myocardial perfusion deficits are produced predominantly by regional reduction in blood flow. Initial images are done after injection of ^{201}Tl during stress, and rest images are done about four hours later. Disappearance of initial perfusion defects on delayed images indicates redistribution of the agent caused by slower clearance of ^{201}Tl from underperfused compared to normally perfused regions. Tc-99m-labelled perfusion agents such as $^{99\text{m}}\text{Tc}$ sestamibi and $^{99\text{m}}\text{Tc}$ -teboroxine have been used in recent years because of better imaging properties compared to ^{201}Tl . Because $^{99\text{m}}\text{Tc}$ -sestamibi does not redistribute, separate injections must be done for rest-stress studies.

Nuclear perfusion imaging may be done after injection of the agent at rest or during peak of exercise or pharmacological stress. Pharmacological stress or near maximal vasodilatation is induced by dipyridamole, adenosine or dobutamine. Based on the changes in regional perfusion defects from stress to rest states, defects can be diagnosed as fixed, reversible or partially reversible. Fixed defects are those which are nearly identical in both states and indicate infarction. Reversible defects are present on stress images but not on rest images and indicate ischaemia without infarction. Partially reversible defects show a defect during stress in which the concentration of the agent in the defect increases on the delayed rest image but does not equalize with the normal regions. This pattern is considered to represent a mixture of nonviable and viable but ischaemic myocardium.

The clinical applications of myocardial perfusion imaging are: detection of

coronary artery disease (CAD) in asymptomatic and symptomatic patients; estimation of the severity of CAD; distinction between single and multivessel CAD; stratification of risks for coronary events; risk stratification after acute myocardial infarction; and risk stratification in patients undergoing noncardiac surgery (fig. 7.15).



Nuclear angiography can also be done in two different ways.

1. First-pass technique involves rapid i.v. injection of a bolus of a simple radionuclide (^{99m}Tc pertechnetate). Its passage through the cardiac chambers is then recorded. The method is most useful for the study of intracardiac shunts.
2. Multigated equilibrium studies (MUGA) follow injection of an isotope which remains fixed within the vascular space (^{99m}Tc -labelled human serum albumen or red blood cells) thus labelling the total blood pool. Cardiac movement is then assessed by linking the recorder to ECG gating over several hundred cardiac cycles, the data being accumulated into one totalised cycle. The images can then be transferred to a continuous loop of video film for viewing in cine mode. Abnormalities of ventricular function, particularly those due to ischaemic heart disease and cardiomyopathy are readily assessed by this method. Computer manipulation of the data also enables ventricular ejection fractions to be obtained.

7.2. Pathologic considerations

There are many ways to classify cardiac diseases. A popular classification uses two large categories, congenital and acquired cardiac disease. Congenital cardiac disease is further subdivided into cyanotic and acyanotic types. Most books on cardiology prefer this method. For the non-cardiologist, a physiologic approach affords an understandable and useful basis for dealing with congenital and acquired heart disease. In addition to this physiologic approach, it is preferable to evaluate patients with cardiac disease on the basis of their age. This discussion will focus on the plain film evaluation of these patients, since that is the type of imaging examination choice order first and with which you will be most familiar. Once you

have an idea of what kind of cardiac disease you are dealing with you can order more sophisticated imaging procedures, such as echocardiography, angiography, or MRI, to make a definitive diagnosis.

Adult Patients

From a physiologic standpoint, all types of cardiac disease may be categorized into the following:

- I. Obstruction.
- II. Volume overload.
 - A. Shunt (right-to-left, left-to-right).
 - B. Valvular insufficiency.
- III. Disorders of contraction or relaxation.
 - A. Myocardial disease.
 - B. Conduction disorders (arrhythmias).
- IV. Combination of the preceding.

No matter what the etiology is, all cardiac diseases will show evidence of one or more of these patterns.

Evaluation of the pulmonary vascularity is an important step that enables exclusion of many diseases. The physiologic type of disease may be inferred from the pattern of pulmonary blood flow. Pulmonary vascularity may be normal, decreased, or increased. Normal pulmonary vessels should be about the same size as that of an accompanying airway. Any significant disparity in size is abnormal.

Surprising as it may seem, patients with normal pulmonary vascularity may have significant cardiac disease. In these patients, the heart has compensated for the abnormality by enlarging. The pulmonary vascularity remains normal until the heart decompensates. Diseases that produce cardiac chamber enlargement without appreciable change in the pulmonary vascularity until decompensation occurs include cardiomyopathy, coronary artery disease, hypertensive cardiovascular disease, aortic stenosis, and coarctation of the aorta. All these conditions except coarctation and a form of aortic stenosis are acquired.

Decreased vascularity indicates a severe obstruction to the outflow of blood from the right ventricle, usually at the pulmonic valve or subvalvular level. Patients exhibiting this pattern are often visibly cyanotic. If the decreased vascularity is of a diffuse nature, a congenital anomaly is most likely. This pattern is seldom seen in the adult, since the abnormalities that produce this pattern will result in the patient's death unless corrective surgery is performed during childhood.

Decreased vascularity may be apparent locally or unilaterally. A local decrease

in vascularity may be the result of pulmonary embolism (Westermark sign), emphysema, or scarring with rearrangement of vessels in a lung. Increased vascularity is of four types: (1) shunts, (2) pulmonary venous obstruction, (3) precapillary hypertension, and (4) high-output state.

Shunts represent an increased flow through the pulmonary bed. They are characterized by large vessels in the upper and lower lobes. A similar pattern may occur in high-output states. In patients with a shunt who are not in congestive heart failure, the redistribution of blood will be in the same proportion as that occurring normally: greater to the lung bases than to the upper lobes. This vascular pattern occurs most commonly in a left-to-right shunt at the cardiac or great vessel level (septal defect or patent ductus arteriosus). This pattern is uncommon in adults since the condition is usually diagnosed and treated in childhood.

Patients with pulmonary venous obstruction (PVO) demonstrate large veins in the upper lobe as a reflection of reversal of the normal flow pattern (fig. 7.16).



Fig. 7.16. The frontal chest radiograph. Cardiomegaly, heart size exceeding normal dimensions. Cardiomegaly is usually initially identified by plain radiography. In adults, cardiomegaly is considered to be present if the ratio of the maximum cardiac diameter to the maximum thoracic dimension on a standard posteroanterior radiograph exceeds 0.50. This constitutes a cardiothoracic ratio greater than 0.50. Alveolar pulmonary edema. Engorgement of the pulmonary veins.

This indicates increased left atrial pressure. Severe PVO is manifested by pulmonary edema and prominent interlobular septal (Kerley) lines.

Patients with precapillary hypertension (pulmonary arterial hypertension) have large central vessels that taper rapidly into small vessels peripherally. This is referred to as centralized flow and occurs in patients with severe pulmonary disease, recurrent pulmonary embolism, and Eisenmenger phenomenon.

Once the pulmonary vascular pattern is decided on, look at the heart to determine if specific chamber enlargements are present. If there is evidence of left atrial enlargement (with or without PVO), rheumatic heart disease (mitral stenosis) or an obstruction at or proximal to the mitral valve is present. If there is evidence of left

ventricular enlargement with a "concavity" in the area of the main pulmonary artery, the disease is one of left ventricular stress such as hypertensive cardiovascular disease, coronary artery disease, aortic stenosis, or coarctation of the aorta.

Pulmonary venous obstruction plus left ventricular configuration (LVC) equals left ventricular stress with failure. All the preceding conditions occur with this pattern. It is possible to further narrow the list of causes in this situation by scanning the film for evidence of rib notching and/or decreased size of the aortic knob, as in aortic coarctation, or for calcification in or about the aortic valve, as in calcific aortic stenosis.

A high-output state, such as severe anemia or thyrotoxicosis, may result in increased vascularity with a normal distribution as a result of the increased volume being pumped through the heart. The heart itself may be normal or slightly enlarged as a result of this increased activity.

Pericardial effusion must always be considered when evaluating a patient with the enlarged heart. The diagnosis may be made by one or a combination of imaging studies. In general, a large heart of nonspecific configuration, particularly in the absence of pulmonary venous engorgement, should suggest a pericardial effusion. Cardiac fluoroscopy is a useful procedure for the diagnosis of pericardial effusion. A dampened cardiac pulse in the presence of an enlarged heart and no congestive heart failure suggests the condition. However, this is by no means pathognomonic, since a poorly contracting heart in a patient with cardiac arrhythmia, scarred myocardium, or infiltrated myocardium will produce poor pulsations. A pulsating subepicardial fat line within the immobile fluid band is, however, diagnostic of pericardial effusion (fig. 7.17).

Echocardiography is probably the most useful examination for detecting this condition and with the least risk to the patient. Ultrasonic shadows reflected off the pericardial and myocardial surfaces will demonstrate an abnormal collection of fluid in the pericardial sac (norm size of fluid up to 4 mm). Computerized tomography scanning may be also used to diagnose pericardial effusion. A CT number near the density of water surrounding the heart ensures the diagnosis. This diagnosis is usually made as an incidental finding in patients studied for other reasons.

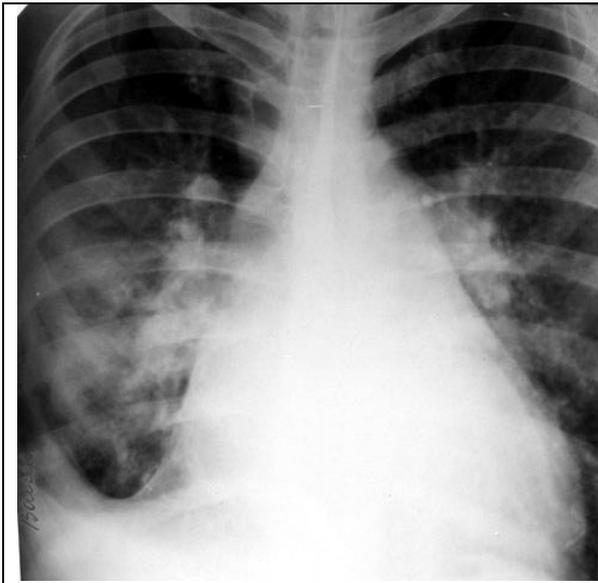


Fig. 7.17. The frontal chest radiograph. Pericardial effusion: a smoothness of contours of heart, its triangular form. Pleural effusion: In the bottom department of the right pulmonary field shadow is defined. Shadows of hilums are increased, because of expansion of vascular trunks forming them.

Trauma. Patients who have suffered severe thoracic trauma may have injury to the heart or great vessels. The most common mechanism for this is an accident in which the unrestrained driver of a motor vehicle strikes the steering wheel. Radiographically, the most common finding is a widened superior mediastinal shadow that is fuzzy. You should remember, however, that a supine radiograph in a large patient may simulate this appearance. With this in mind, you should make every effort to obtain an erect film. When this fails, and in the appropriate clinical setting, an aortogram should be obtained to rule out aortic injury.

Mitral regurgitation. Mitral regurgitation, systolic flow of blood from the left ventricle into the left atrium due to insufficient closure of the mitral valve. It may be caused by pathology of the mitral leaflets, subvalvular mechanism (chordae or papillary muscles) or mitral annulus. There are a large number of aetiologies for mitral regurgitation including rheumatic heart disease, infectious endocarditis, ischaemic papillary muscle rupture or traumatic papillary muscle rupture, degenerative cordal rupture, mitral valve prolapse, mitral annular calcification, and congenital lesions such as parachute mitral valve and atrioventricular septal defect. The haemodynamic consequence of mitral regurgitation is systolic increase in left atrial pressure and pulmonary venous pressure during systole. The increase in pulmonary venous pressure is usually less severe than with mitral stenosis. However, severe elevation in pulmonary venous pressure occurs with acute onset of regurgitation. Mitral regurgitation imposes a volume load on the left atrium and ventricle. Left ventricular end-diastolic volume is increased. The total stroke volume of the left ventricle is increased since it includes the effective stroke volume (blood

ejected to the aorta) and the regurgitant volume.

Plain radiography shows various degrees of pulmonary venous hypertension and cardiomegaly. The severity of pulmonary venous hypertension is generally less than in predominant mitral stenosis. Cardiomegaly is a consequence of left atrial and left ventricular enlargement (fig. 7.18).

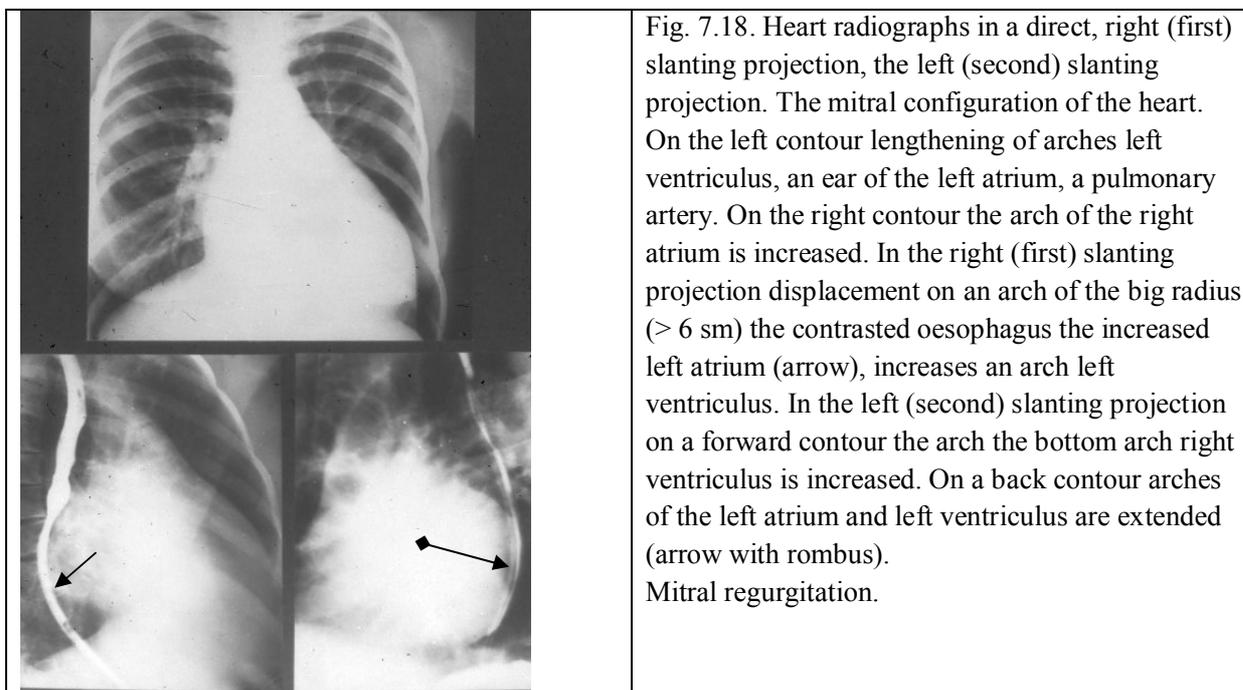


Fig. 7.18. Heart radiographs in a direct, right (first) slanting projection, the left (second) slanting projection. The mitral configuration of the heart. On the left contour lengthening of arches left ventriculus, an ear of the left atrium, a pulmonary artery. On the right contour the arch of the right atrium is increased. In the right (first) slanting projection displacement on an arch of the big radius (> 6 sm) the contrasted oesophagus the increased left atrium (arrow), increases an arch left ventriculus. In the left (second) slanting projection on a forward contour the arch the bottom arch right ventriculus is increased. On a back contour arches of the left atrium and left ventriculus are extended (arrow with rhombus). Mitral regurgitation.

Right-sided chamber enlargement may be caused by pulmonary arterial hypertension or concurrent tricuspid regurgitation. In the absence of associated aortic valve disease, the ascending aorta is inconspicuous. The left atrial appendage is usually enlarged in rheumatic mitral regurgitation but may not be recognizable with nonrheumatic aetiologies. Acute mitral regurgitation such as occurs with ruptured papillary muscle may cause severe alveolar pulmonary oedema, sometimes with a normal heart size.

The M-mode echocardiogram shows abnormal mitral leaflet closure patterns depending upon the type of mitral regurgitation. These consist of incomplete closure, mitral valve prolapse, ruptured chordae tendineae or flail mitral valve. The flail valve shows erratic systolic motion into the left atrium.

Two-dimensional echocardiography shows the above signs described for M-mode echocardiography. This study may reveal the aetiology of the regurgitation by showing mitral valve prolapse; papillary muscle rupture or chordal rupture; thickened leaflet with fused commissure and decreased motion in rheumatic disease; vegetations

or perforated leaflet in infectious endocarditis; parachute or cleft mitral valve in congenital disease; or mitral annular calcification. In chronic mitral regurgitations left ventricular volumes are increased and can be effectively monitored with two-dimensional echocardiography. The extent of the increase in left ventricular volumes is a prognostic indicator for surgical outcome. A left ventricular systolic volume over 60 ml/m^2 is associated with a worse prognosis. Left ventricular dimensions at end diastole greater than 7 cm and at end systole greater than 5 cm are indicative of severe diseases.

Pulse wave Doppler echocardiography is extremely sensitive for detecting mitral regurgitation; it appears as a turbulent systolic signal within the left atrium directed away from the transducer. The extent of the penetration and area of the regurgitant jet can be used to estimate the severity (fig. 7.19).

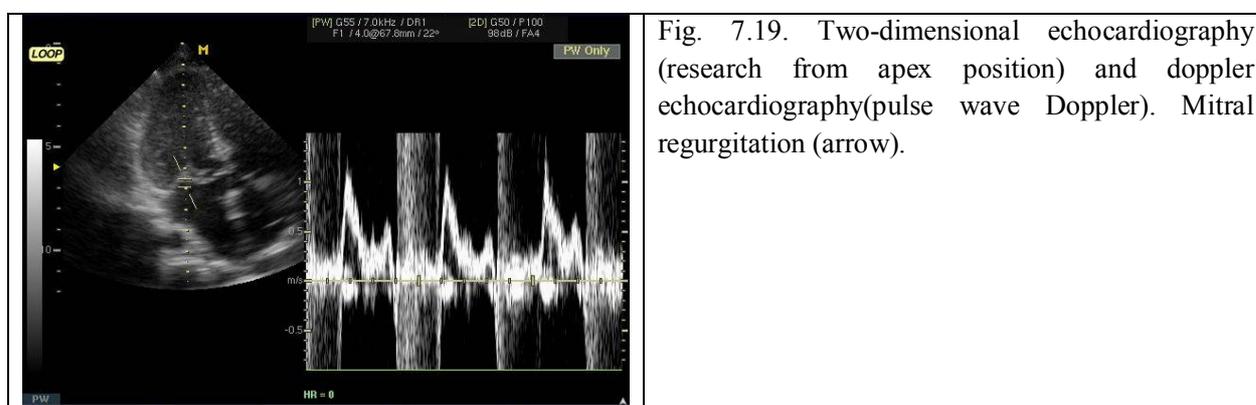


Fig. 7.19. Two-dimensional echocardiography (research from apex position) and doppler echocardiography(pulse wave Doppler). Mitral regurgitation (arrow).

Colour flow Doppler provides a nearly real-time flow map of the origin and direction of mitral regurgitation. Large colour jets that occupy more than a half of the left atrium, extend to the posterior portion of the atrium or into the appendage or pulmonary veins indicate significant regurgitation.

Left ventriculography shows escape of contrast media from the left ventricle into the left atrium during systole. Comparison of the intensity of opacification of the left atrium with the left ventricle provides a semiquantitative estimate of severity. Quantitative left ventriculography reveals increased left ventricular end diastolic, end systolic and stroke volumes. The regurgitant volume in isolated mitral disease can be calculated as the difference in stroke volume calculated from left ventriculography (end-diastolic – end-systolic volume). Structural abnormalities of the valve such as flail valve or vegetations are revealed by left ventriculography. For the most part, echocardiography has supplanted angiography for the diagnosis and assessment of severity of mitral regurgitation.

Preoperative catheterization is performed mainly for the purpose of coronary arteriography in patients over 40 years old.

Cine MRI displays the regurgitant jet as a signal void emanating from the mitral valve projecting into the left atrium during systole. The size of the signal void bears a rough relationship to the severity of regurgitation. Cine MR images encompassing the entire heart can be used to measure left atrial and ventricular volumes with high precision and reproducibility. Velocity-encoded cine MRI can be used to measure the volume of regurgitation. It can be measured as the difference in the inflow volume across the mitral annulus in diastole and the outflow volume through the ascending aorta in systole.

Mitral stenosis. Mitral stenosis, abnormal resistance to blood flow from the left atrium to the left ventricle due to narrow mitral orifice. There are a number of causes of mitral stenosis but most cases are due to rheumatic heart disease. Rarely, it is caused by congenital defects such as parachute mitral valve or mitral annular and valvular hypoplasia. The mitral valve can also be obstructed secondarily by tumours such as left atrial myxoma or left atrial thrombus or rarely by mitral annular calcification. Deterioration of artificial mitral valves can cause mitral stenosis. Mitral stenosis is complicated frequently by chronic atrial fibrillation and left atrial thrombus. The haemodynamic consequences of mitral stenosis are increases in left atrial, pulmonary venous and pulmonary arterial pressures. In some patients severe pulmonary arterial hypertension develops, causing secondary pulmonary regurgitation, tricuspid regurgitation and substantial right-sided chamber enlargement.

The chest radiography demonstrates signs of pulmonary venous hypertension in nearly all patients with haemodynamically significant mitral stenosis. In milder disease, there is merely equalization of the calibre of blood vessels in the upper and lower lobe regions, while with other cases there is interstitial and/or alveolar pulmonary oedema. The cardiac size is usually not substantially enlarged but there is invariably left atrial enlargement. The left atrial appendage is enlarged, especially in patients in whom stenosis is caused by rheumatic heart disease. In isolated mitral stenosis the left ventricle is not enlarged. Often the combination a mitral stenosis and mitral regurgitation is observed (fig. 7.20).

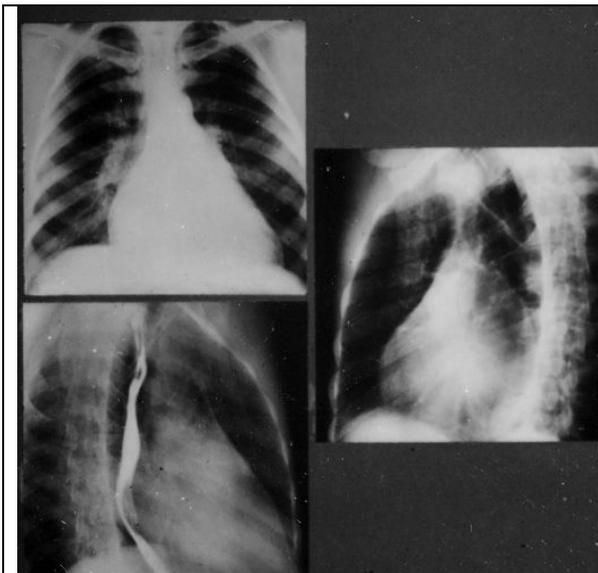


Fig. 7. 20. Heart radiographs in a direct, right (first) slanting projection, left (second) slanting projection. The mitral configuration of the heart. On the left contour lengthening of the left ventriculus arches, ear of the left auricle, pulmonary artery is detected. On the right contour the arch of the right auricle is increased. In the right (first) slanting projection on the arch of small radius (<6 sm) the contrasted oesophagus is displaced due to the increased left auricle, increases the left ventriculus arch. In the left (second) slanting projection on a forward contour the arch the bottom arch right ventriculus is increased. On a back contour arches of the left auricle and left ventriculus are extended. Mitral regurgitation and mitral stenosis.

However, mitral regurgitation is sometimes also present which may cause left ventricular enlargement. The right ventricle may be either slightly or substantially enlarged depending on the severity of pulmonary arterial hypertension. Pulmonary arterial hypertension is evident by enlargement of the main pulmonary artery. Calcification of the mitral valve, left atrial appendage or left atrial wall may be evident on the radiograph or revealed by fluoroscopy.

The M-mode echocardiography demonstrates slow initial closure of mitral valve (decreased EF slope), anterior motion of the posture leaflet as well as the anterior leaflet, decreased diastolic separation of leaflets, and thickened leaflets (fig. 7.21).

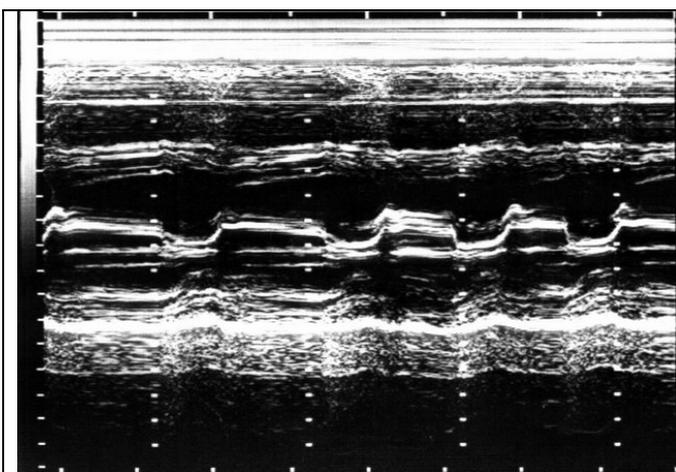


Fig. 7.21. M-mode echocardiogram (parasternal a position). Mitral stenosis: fibrosis of leaflets and restriction of mobility of a back leaflet of mitral valve.

Two-dimensional echocardiography shows thickened and relatively immobile

leaflets, doming of the valve, chordal foreshortening and thickening. It may also disclose calcification of the valve or subvalvular apparatus. Doppler echocardiography shows characteristic features. The normal Doppler mitral inflow pattern shows two peaks for early diastolic filling (E peak) and late filling atrial contraction (A peak). The normal peak mitral inflow velocity is less than 1.3 m/sec. In mitral stenosis, the peak is usually increased to 1.5 to 3.0 m/sec, employing the modified Bernoulli equation. The rate of left ventricular filling decreases as reflected by reduced downslope of the E wave. Quantification of the Doppler flow pattern in mitral stenosis is also made by the "pressure half time" which is the time needed for the initial diastolic gradient to decrease by one half. The pressure half time correlates with the valve orifice area. Colour flow Doppler imaging has been used to depict the width of the flow jet across the stenotic valve; width of the inflow jet has been correlated with the orifice area. Transoesophageal echocardiography can provide exquisite detail of the mitral valve morphology and demonstrate thrombus in the left atrium. Left ventriculography demonstrates doming and restricted leaflet motion and a narrowed stream of nonopacified blood flow ("wash in" jet) into the opacified left ventricle during diastole. The thickened and fused chords of the valve may be shown as lucent extensions of the papillary muscle towards the valve leaflets. This finding indicates the likelihood of significant subvalvular obstruction as well as valvular stenosis. Abnormal motion of the anterior leaflet of the mitral valve may be assessed also in the left anterior oblique view. The normal valve displays biphasic motion in diastole with opening towards the left ventricle in early diastole followed by a drift back toward the annulus and then a second presystolic opening toward the left ventricle with atrial systole. In mitral stenosis, the motion is continuously toward the left ventricle in diastole because a pressure gradient exists between the left atrium and ventricle throughout diastole.

Many patients with predominant mitral stenosis also have some degree of mitral regurgitation revealed by left ventriculography.

Cine MRI shows a signal void caused by the flow jet across the stenotic mitral valve. It may also reveal the signal void caused by associated mitral regurgitation. This imaging sequence usually demonstrates normal left ventricular size and contraction. Highly accurate and reproducible measurement of left atrial and ventricular volumes are provided from cine gradient MR images encompassing the entire heart. Velocity-encoded cine gradient echo image acquired perpendicular to the direction of flow across the valve orifice can be used to measure the peak flow velocity and enable estimation of the pressure gradient. Spin-echo and gradient-echo

imaging are effective for demonstrating left atrial thrombus.

Aortic stenosis, narrowing of the valve between the left ventricle and the ascending aorta causing a pressure gradient during systole. It is usually caused by limitation of motion of the aortic valve cusps (valvular aortic stenosis) but can also occur in the aorta within a few cm of the valve, supra-avalvular aortic stenosis or beneath the valve, subvalvular aortic stenosis. Commonly, aortic stenosis and aortic regurgitation coexist but one of the lesions is usually dominant. Left ventricular systolic pressure is elevated. Left ventricular wall stress is frequently increased; left ventricular hypertrophy tends to equalize wall stress even in the presence of considerable increase in left ventricular systolic pressure during the compensated state. Inadequate hypertrophy and myocardial failure in advanced disease is associated with marked increase in wall stress, left ventricular dilatation and eventually subendocardial myocardial ischaemia. The causes of valvular stenosis include congenital abnormalities such as bicuspid and unicuspid valves and deformed tricuspid valves. Acquired abnormalities include rheumatic fever and degenerative scarring and calcification.

Plain radiography varies from entirely normal to severe cardiomegaly and pulmonary oedema. The radiograph of neonates with critical aortic stenosis shows pulmonary oedema or pulmonary venous hypertension and cardiomegaly. In both older children and adults there is usually mild or no cardiomegaly and no evidence of pulmonary venous hypertension. The most frequent feature of the plain radiograph is dilatation of the ascending aorta (poststenotic dilatation); aortic enlargement does not usually involve the arch or descending aorta. Aortic valvular calcification bears a rough relationship to the severity of valvular stenosis in patients under 60 years of age. Calcification is readily identified on fluoroscopy but only dense calcification is recognized on plain radiography. Ascending aortography demonstrates restriction of systolic opening (doming) of the thickened aortic valve and a jet of unopacified blood entering the opacified ascending aorta. The aortogram also reveals the extent of dilatation of the ascending aorta. It also displays any diastolic reflux of contrast media into the left ventricle due to associated aortic regurgitation. The severity of valvular aortic stenosis cannot be accurately judged from angiography but rather is reflected by the pressure gradient measured across the valve. Left ventriculography displays the limitation of excursion and thickening of the valve in valvular stenosis. Left ventriculography typically shows normal to slightly reduced left ventricular volumes and increased ejection fraction. Left ventricular wall thickness and myocardial mass are increased (fig. 7.22).

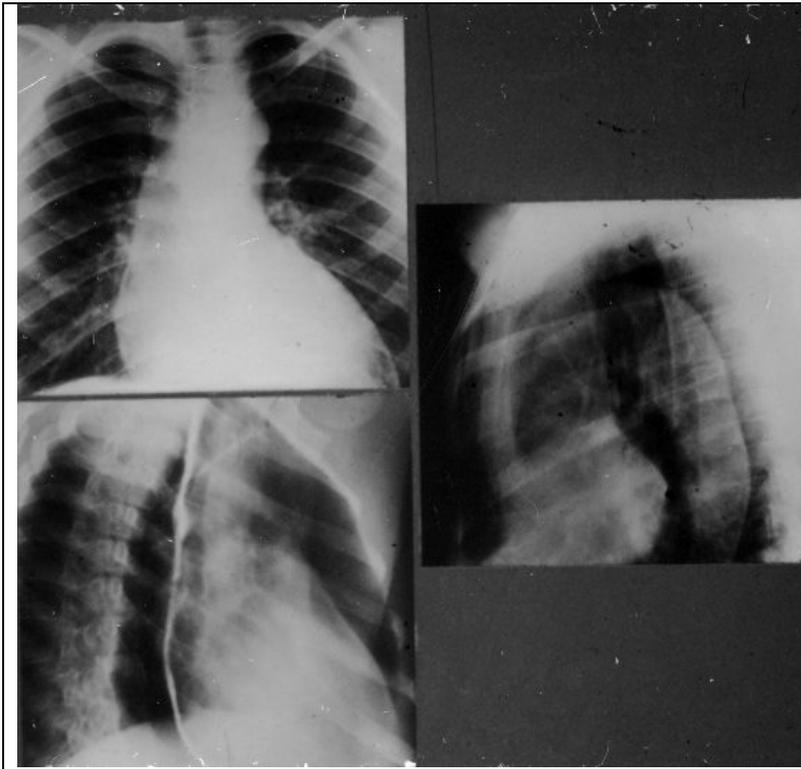


Fig. 7.22. Heart radiographs in a direct, right (first) slanting projection, the left (second) slanting projection. Arches of the ascending aorta and left ventriculus in a direct projection are increased. In the right (first) slanting projection the bottom arch of a forward contour is formed left ventriculus is increased. In the left (second) slanting projection the bottom arch of a back contour is formed left ventriculus which accumulates on a backbone is increased. On a forward contour the ascending part of the aorta is increased, as the angle between an aorta and the right chambers of heart is displaced from top to bottom. Aortic heart disease.

Echocardiography, two-dimensional and Doppler, is the most frequently employed modality for the diagnosis and assessment of severity of aortic stenosis. Colour flow mapping displays the high velocity jet across the valve. It also demonstrates the presence of associated regurgitation. Doppler sampling of the velocity of flow across the aortic valve is used to estimate the severity of aortic stenosis employing the modified Bernoulli equation (fig. 7. 23).

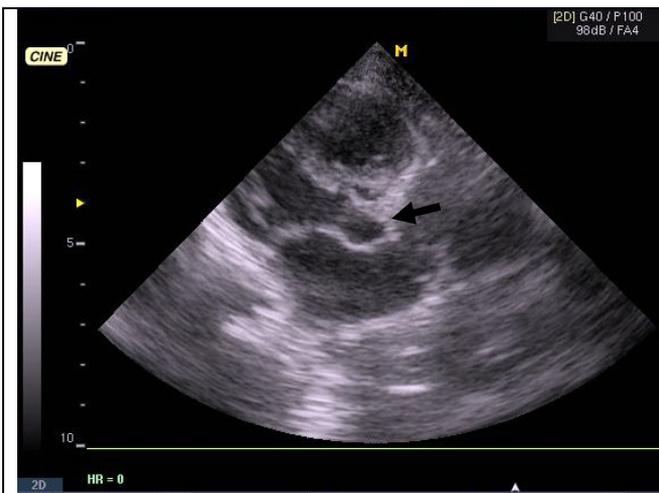


Fig. 7.23. Two-dimensional echocardiography (research from apex position). Aortic stenosis: fibrosis and thickening of leaflets of aortic valve (arrow).

Magnetic resonance imaging (MRI) and computed tomography (CT) can

demonstrate the precise dimensions of the dilated ascending aorta. This is useful in monitoring aortic size in patients who develop aneurysmal dilatation as a complication of aortic stenosis. Although not generally used in the evaluation of aortic stenosis, cine MRI can define the high velocity jet across the aortic valve. Velocity-encoded cine MRI has been effective for measuring the peak velocity and pressure gradient using the modified Bernoulli equation. Cine MRI is a precise method for quantifying left ventricular volumes and myocardial mass in aortic stenosis.

Aortic regurgitation, retrograde flow across the closed aortic valve during diastole. It is caused by abnormalities of one or more of the following structures: aortic cusp, aortic annulus, aortic sinuses. It is invariably associated with dilatation or aneurysm of the ascending aorta. There are many causes of aortic regurgitation including rheumatic heart disease, infective endocarditis, bicuspid aortic valve, aortoannular ectasia, aortic dissection and aneurysm, and several systemic diseases. The systemic diseases in which aortic regurgitation may be a manifestation are: ankylosing spondylitis, rheumatoid arthritis, Reiter's syndrome, giant cell aortitis, psoriatic arthritis, relapsing polychondritis, cardiovascular manifestation, syphilis, cardiovascular. Mild or moderate aortic regurgitation is frequent in patients with long-standing systemic hypertension. It may also be caused by trauma and radiation therapy. Aortic regurgitation is a frequent complication of valvuloplasty of aortic stenosis. Degeneration or infection of prosthetic valves causes aortic regurgitation. Most aetiologies produce chronic aortic regurgitation. Acute severe regurgitation may be caused by infective endocarditis, trauma and aortic dissection.

Radiography shows cardiomegaly due predominantly to left ventricular enlargement (fig. 7.24).

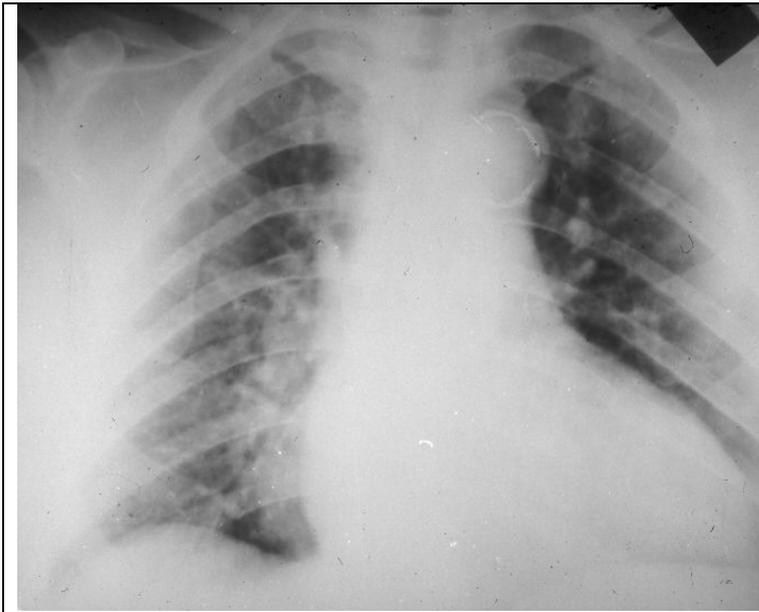


Fig. 7.24. The frontal chest radiograph. The first and fourth arches on the left contour are increased. Calcification of aorta arches. Aortic configuration of the heart.

Typically, enlargement of the ascending arch and descending thoracic aorta is evident.

For most of the course of chronic aortic regurgitation there is no pulmonary venous hypertension or pulmonary oedema. On the other hand, acute aortic regurgitation not uncommonly causes severe pulmonary oedema and little or no cardiomegaly.

Angiography demonstrates the presence and severity of aortic regurgitation consisting of retrograde diastolic flow of opacified blood into the left ventricle. The density of opacification of the left ventricle relative to opacification of the aorta is used as a semiquantitative method for grading the severity of aortic regurgitation.

Echocardiography, either transthoracic or transoesophageal, is the most frequently employed technique for the diagnosis and assessment of the severity of aortic regurgitation. Doppler colour flow mapping is highly sensitive for identifying aortic regurgitation but provides only a semiquantitative assessment of severity. Echocardiography is very effective for demonstrating vegetations on the aortic valve indicative of infective endocarditis. Transoesophageal echocardiography is the preferred noninvasive technique for the evaluation of regurgitation of prosthetic aortic valves including suspected infective endocarditis. Echocardiography is used to monitor increases in left ventricular dimensions, volumes and ejection fraction in order to define the severity of regurgitation and as a guide to timing of valve replacement (fig. 7.25).

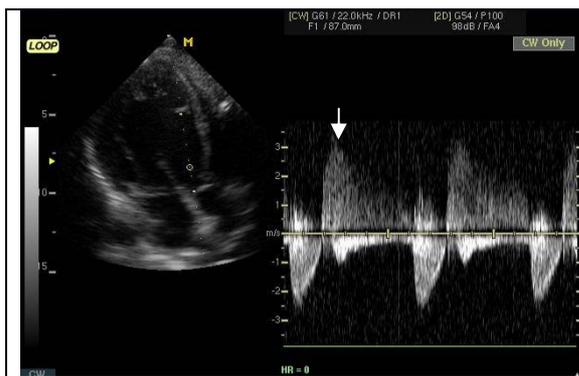


Fig. 7.25. Two-dimensional echocardiography (research from apex position) and doppler echocardiography (continuous wave Doppler). Aortic insufficiency: aortic regurgitation (arrow).

Magnetic resonance imaging is highly accurate for demonstrating the presence of aortic regurgitation. On cine gradient echo images the regurgitant jet is displayed as a signal void emanating from the closed aortic valves into the left ventricle during diastole. The size of this signal void serves as a semiquantitative estimate of the volume of aortic regurgitation. Magnetic resonance imaging is the optimal technique for detecting abnormalities of the aortic sinuses, annulus, and ascending aorta associated with aortic regurgitation. It is also the preferred method for monitoring the dimension of the sinus and ascending aorta in patients with aortoannular ectasia as the cause of aortic regurgitation.

Coronary artery disease. Echocardiograms show contraction function infringement of separate sites of the left ventriculus wall in the form of reduction of amplitude of movement and myocardium thickening in systole; decrease in fraction of left ventriculus emission. Echocardiogram is a noninvasive test that uses ultrasound images of the heart. This test is more expensive than ECG, but it can be very valuable, particularly in identifying whether there is damage to the heart muscle and the extent of heart muscle damage. Stress echocardiogram may be performed to further evaluate abnormal findings from an exercise treadmill test or a routine echocardiogram. Examples include identifying exactly which part of the heart may be involved and quantifying how much muscle has been infected. It may be the first test done when the exercise treadmill test cannot be performed due to certain abnormal rhythms.

Radionuclide imaging is useful for diagnosing and determining:

- Severity of unstable angina when less expensive diagnostic approaches are unavailable or unreliable
- Severity of chronic coronary artery disease
- Success of surgeries for coronary artery disease.
- Whether a heart attack has occurred

Myocardial perfusion (blood flow) imaging test (also called the thallium stress test). Presence of sites of a myocardium with accumulation reduction of

radiofarmaceutical. This radionuclide test is typically used with an exercise stress test to determine blood flow to the heart muscles. It is a reliable measure of severe heart events. It may be useful in determining the need for angiography if CT scans have detected calcification in the arteries. About a minute before the patient is ready to stop exercising, the doctor administers a radioactive tracer into the intravenous line. Tracers include thallium, technetium, or sestamibi. Immediately afterwards, the patient lies down for a heart scan. If the scan detects damage, more images are taken 3 or 4 hours later. Damage due to a prior heart attack will persist when the heart scan is repeated. Injury caused by angina, however, will have resolved by that time.

Angiography is an invasive test. It is used for patients who show strong evidence for severe obstruction on stress and other tests, and for patients with acute coronary syndrome. It is required when there is a need to know the exact anatomy and disease present within the coronary arteries. A limitation of angiography is that it is not always the most occluded (blocked) blood vessel that causes the next heart attack. In an angiography procedure:

- A narrow tube is inserted into an artery, usually in the leg or arm, and then threaded up through the body to the coronary arteries.
- A dye is injected into the tube, and an x-ray records the flow of dye through the arteries.
- This process provides a map of the coronary circulation, revealing any blocked area.

Magnetic resonance angiography (MRA). MRA is a newer noninvasive imaging technique that can provide three-dimensional images of the major arteries to the heart.

Computed tomography (CT) scans may be used to evaluate coronary artery disease.

Calcium scoring CT scans of the heart. May be used to detect calcium deposits on the arterial walls. The presence of calcium correlates well with the presence of atherosclerosis of the heart. If the calcium score is very low, a patient is unlikely to have coronary artery disease. A higher calcium score may indicate an increased risk of current and future coronary artery disease. However, the presence of calcium does not necessarily signify narrowing of the arteries that would need further immediate evaluation or treatment.

CT angiography. CT scans are also used to visualize the coronary arteries. When compared to invasive angiography, CT angiography is not as accurate in identifying who truly has coronary artery disease and who does not. Other types of

newer CT techniques include electron beam computed tomography and multidetector computed tomography.

Myocardial infarction, death of myocardial cells due to inadequate blood supply. The two main types are transmural and subendocardial infarction. Most myocardial infarctions result from atherosclerosis of the coronary arteries usually with superimposed thrombosis. Rarely, infarction can occur as a consequence of coronary arterial spasm, mural dissection, trauma or embolization. Infrequently, infarction occurs as a consequence of drastically increased myocardial oxygen demands causing imbalance in oxygen demand–supply ratios in diseases with severe left ventricular hypertrophy such as aortic stenosis and hypertrophic cardiomyopathy. Myocardial infarction most frequently occurs in the left ventricle; however, a substantial number of patients with inferior infarction have some infarction of the right ventricle also. Isolated infarction of the right ventricle is infrequent. The major pathophysiological consequences of acute myocardial infarction are diminished systolic function due to loss of functioning myocardium. With extensive infarction stroke volume and cardiac output are reduced; this may result in cardiogenic shock. Another consequence of acute infarction is diastolic dysfunction resulting in a decrease in ventricular compliance with elevation in left ventricular diastolic and pulmonary venous pressure. This may cause pulmonary oedema. The major complications of myocardial infarction are: heart failure, cardiac rupture, true left ventricular aneurysm, false (pseudo) aneurysm, acute mitral regurgitation from papillary muscle rupture, ventricular septal rupture (defect) and mural thrombus with or without peripheral embolization. Acute pericarditis may develop in some patients with transmural infarction (Dressler's syndrome).

Plain radiography is normal in about half of patients presenting with acute myocardial infarction. The most frequent abnormal finding is pulmonary venous hypertension or oedema without discernible cardiomegaly. The chest X-ray discloses pulmonary overcirculation and oedema in patients with ventricular septal rupture. A dramatic increase in cardiac size several days after infarction suggests pericardial effusion. Ventricular aneurysm is depicted as an abnormal bulge along the left ventricular margin. It is usually located in the anterior, lateral or apical region with true aneurysms. False (pseudo)aneurysms are usually larger and located on the posterior or diaphragmatic margin. Sudden onset or worsening of pulmonary oedema occurs with papillary muscle rupture; pulmonary oedema confined to or worse in the right upper lobe is particularly characteristic.

Echocardiography demonstrates abnormal regional wall motion of the left

ventricle in nearly all patients with acute infarction. A wall motion abnormality may not be evident in some patients with nontransmural infarction. Echocardiography can also be used to monitor remodelling of the ventricle after infarction and to follow end-diastolic and end-systolic size. Doppler and colour flow mapping echocardiography demonstrate mitral regurgitation and flail motion of a mitral leaflet due to papillary muscle dysfunction or rupture.

Radionuclide imaging using blood pool imaging demonstrates regional wall motion abnormality and in some instances reduced ejection fraction in acute infarction. Perfusion imaging at rest, employing thallium-201 or technetium-99m sestamibi demonstrates a perfusion deficit. Infarct avid tracers such as technetium-99m pyrophosphate show accumulation at the site of infarction (hot spot imaging). Perfusion imaging within the first 6 hours after onset of symptoms invariably demonstrates a perfusion defect but at a later time interval reperfusion may occur spontaneously so that a perfusion deficit is not evident. In patients who have successful therapeutic reperfusion of acute infarction ^{99m}Tc sestamibi perfusion imaging shows a decrease in size of the perfusion defect and can confirm the effectiveness of thrombolytic agents or acute catheter interventions.

CT and MRI have been employed to demonstrate complications of acute myocardial infarction. They show the presence, size and type of ventricular aneurysm. False aneurysms are characterized as large in size with a narrow ostium. CT and MRI are more accurate than echocardiography or contrast X-ray ventriculography for demonstrating mural thrombus. CT and cine MRI can be used to depict the regional wall motion abnormality and to quantify ventricular volumes. Magnetic resonance imaging shows increased signal intensity on T2-weighted spin echo images and greater contrast enhancement on T1 spin echo images of the acutely infarcted myocardium compared with normal myocardium. Serial cine MRI studies can be used to monitor left ventricular remodelling after acute infarction.

Left ventriculography is infrequently done in patients with acute infarction while coronary arteriography in recent years has been performed with increasing frequency in order to guide percutaneous transluminal interventional procedures. Left ventriculography documents a regional wall motion abnormality in acute infarction and is sometimes later used to evaluate complications of infarction. Coronary arteriography usually shows total or near total occlusion of a coronary artery. The occlusion is usually due to acute thrombosis at the site of a nonobstructive or obstructive plaque in the coronary artery. Interestingly, the acute thrombosis is frequently not at the site of the most severe stenosis. Arteriography demonstrates

reperfusion of the vessel after thrombolysis and/or angioplasty.

Aneurysm, thoracic aorta, focal or diffuse dilatation of the thoracic aorta usually caused by degenerative diseases such as atherosclerosis. The normal diameter of the thoracic aorta is less than 4.0 cm for the ascending, and less than 3.0 cm for the descending portions. A diameter exceeding 5 cm is usually considered as aneurysm. A diameter of the aorta greater than 1.5 times of the normal diameter also constitutes aneurysm. Aneurysms may be fusiform (concentric radial dilatation) or saccular (eccentric radial dilatation). Atherosclerosis and cystic medial necrosis usually produce fusiform aneurysms while infections cause saccular aneurysms (mycotic aneurysm). True aneurysms have all three layers of the wall while false aneurysms consist only of media. Infection and trauma cause false aneurysms. Aneurysms may be caused by eccentric jet flow across a stenotic or nonstenotic bicuspid aortic valve or coarctation of the aorta.

Plain radiography demonstrates generalized or focal bulging of the aortic contour. Aneurysm of the ascending aorta causes enlargement of the right superior mediastinum and obliteration of the retrosternal air space (fig. 7.26).

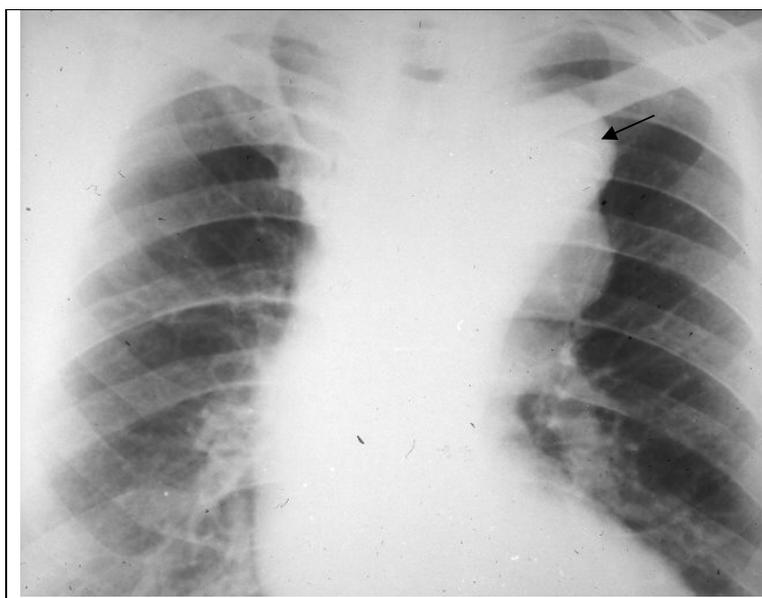


Fig. 7.26. The frontal chest radiograph. The size of the aorta arch is sharply increased (arrow). Aneurysm of the aorta arch.

The aneurysmal contour not uncommonly is calcified. Definition of the diameter and extent of aneurysm can be provided by aortography, CT, MRI and magnetic resonance angiography (MRA). Currently, the preferred imaging modalities for initial diagnosis and monitoring of the diameter are MRI, MR angiography and spiral or electron beam CT. These modes allow to estimate the form, diameter, extent, a status of surrounding tissues, presence clot of blood, wall stratification of aorta.

Aneurysm, abdominal aorta. A diameter exceeding 2.0 cm is considered aneurysmal while a diameter over 4.5–5.0 cm indicates the need for early surgery. Most are fusiform (concentric radial dilatation) but infrequently may be saccular (eccentric radial dilatation). Plain radiography may suggest the presence and size of the aneurysm by showing aortic calcification. Initial diagnosis and monitoring of maximum diameter is now usually done by ultrasonography (fig. 7.27).

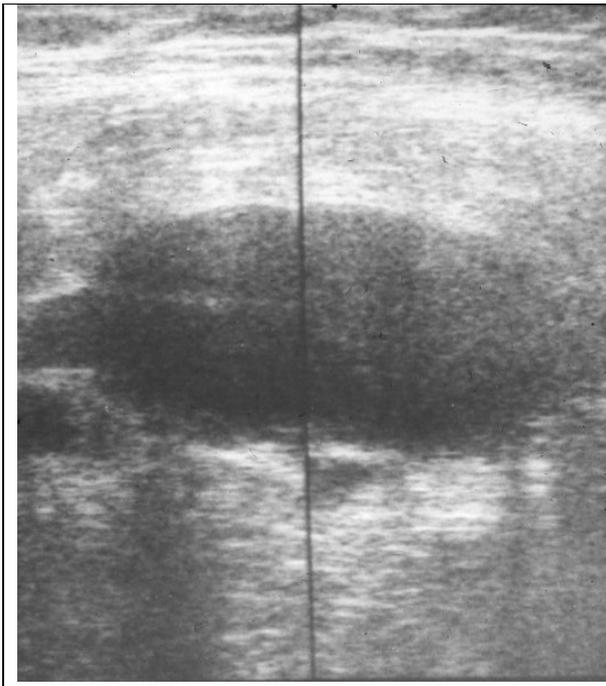


Fig. 7.27. Ultrasound examination of abdomen cavity.

Sharply increased abdomen part of the aorta.
Abdominal aortic aneurysm.

Preoperative evaluation is performed by either X-ray angiography, CT angiography or MR angiography (fig. 7.28).



Fig. 7.28. Digital aortography. Abdominal aortic aneurysm: local expansion of an aorta (arrow).

Each of these studies can define the relationship of the aneurysm to the renal, mesenteric, and iliac arteries and exclude significant stenosis of these arteries (fig. 7.29).



Fig. 7.29. Aortography. Embolic occlusion of the right iliac artery (arrow).

MRI and CT are more accurate for displaying the maximum diameter and mural thrombus. The major complication is rupture with retroperitoneal haemorrhage.

CHAPTER 8. IMAGING OF GASTROINTESTINAL TRACT AND ITS ACCESSORY DIGESTIVE ORGANS

8.1. Radiological examination of gastrointestinal tract

Radiological methods take leading positions in many-stage process of diagnosing digestive diseases.

Among investigation techniques of the gastrointestinal tract (GT) X-ray examinations are still important in detection of morphological and functional changes in digestive systems.

Primary methods of diagnostics of gastrointestinal diseases are *radiographic contrast study* and endoscopy. Ultrasound, CT, MRI are additional methods.

The basic peculiarities of X-ray examination of gastrointestinal tract:

1. Unlike examinations of bones and lungs, where most important information is provided with the help of radiography, detecting of digestive diseases is based on the combination of fluoroscopy and filming.

Advantage of fluoroscopy:

- Study of motor function of gastrointestinal tract;
- Choice of optimal projection, of the moment of filling and motor activity, and degree of compression for target images.

The fluoroscopy always supplemented by radiography for:

- Visualization of shallow morphological details (1-4 mm);
- Documenting of the detected modifications, including, rigidities zones of the wall.

In conditions of natural visibility, i.e. without application of contrast agents, only presence and allocation in the alimentary canal of gas, stones or foreign bodies absorbing X-rays can be estimated.

2. The basic method of roentgenological investigation of esophagus, stomach and intestine is injection of contrast agent into the cavity. Suspension of barium sulfate is used at the rate of 100 g of barium sulfate per 100 ml of boiled water.

The peroral contrast study is basic method at examination of esophagus, stomach and small bowel.

The main method of roentgenological investigation of colon and a rectum is retrograde contrast study (irrigoscopy). The peroral method is applied mainly for estimation of colon function.

Barium-containing drugs are contra-indicative for patients with suspicion of gastrointestinal perforation: getting in the abdominal cavity leads to severe peritonitis.

In this case and in the early postoperative period water-soluble contrast agent is used at anastomoses imposed on the gastrointestinal tract. When there is risk of aspiration and fistulas in trachea and bronchi use nonionic contrast agent should be used.

3. The important principle of examination of the alimentary canal is two-phase examination. The study of each department of the alimentary canal should be effected at its "tight" filling by contrast agent (single contrast) for definition of 1) position, 2) forms, 3) sizes, 4) contours, 5) ability to shift, and 6) functions of organ; and also at low filling (barium-coated mucosa) - for study of mucosa folds. Sequence of these two phases is various for each department.

The preferred method for routine study is to use thicker preparation of barium and to distend the colon or stomach with gas (air-contrast study). In the first situation, air is introduced through the rectal tube. In the second, gas-releasing preparation is ingested with the oral barium. The resulting study gives very little output, which is often sufficient to reveal subtle abnormalities.

4. Important condition of successful carrying out of examination is palpation and compression of organs with the help of special radiographic cones. All departments of the GT, except for esophagus and rectum, are studied with using dosed compression at various degrees of organs filling with contrast agent.

5. Another principle of GT examination is polypositional, or multiaxial. It includes the change of patient's position for definition of all walls of the investigated organ, its relationship with surrounding tissues.

CT has following priorities at GT examination:

- Estimation of wall thickness of GT organs (if it is adequately stretched) and discernment of its infiltration;
- Detection of intramural and extraorganic pathological modifications;

Express procedure for CT of stomach and colon is the distention of walls by water (normal saline solution). Air, 2 % suspension of barium, water-soluble contrast agent is also applied.

Virtual colonoscopy is performed with the help of helical CT (fig. 8.1, 8.2).

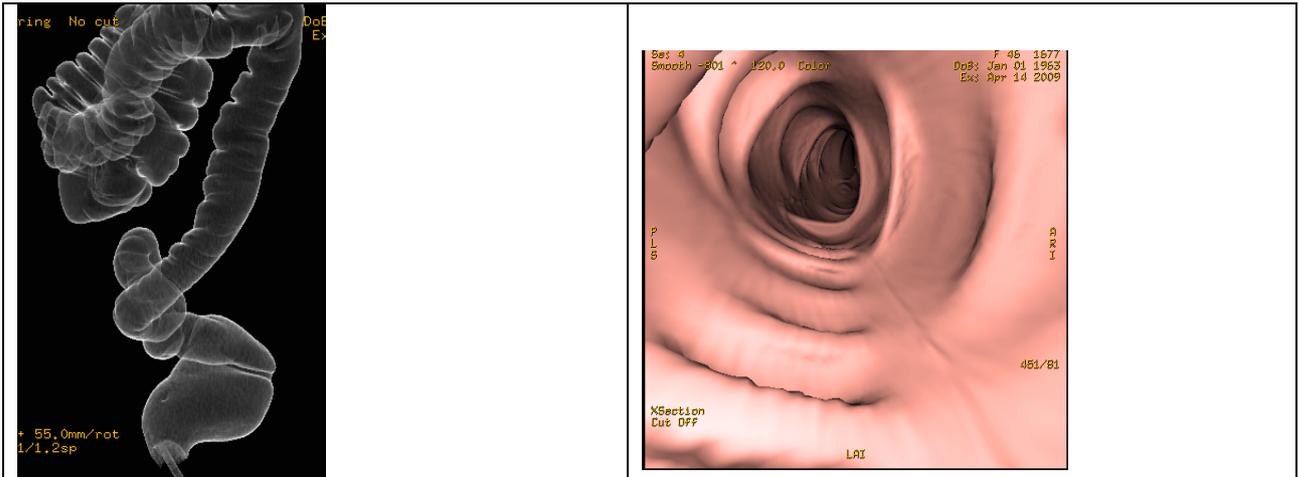


Fig. 8.1. Virtual colonoscopy. Left – 3 D reconstruction, right – intraluminal 3 D reconstruction. Norm.

CT can visualize invasion of a tumour to the wall of GT and condition of surrounding organs.



Fig. 8.2 Virtual colonoscopy. Axial slice.
Narrowing of rectal gleam, non-uniform thickening of walls (arrow) with rough contours.
Malignant tumour (adenocarcinoma) of rectum.

The angiography is applied at a gastrointestinal bleeding for define of indications for surgery treatment .

Ultrasound investigation of GT. The main purpose of transabdominal ultrasound is to identify diseases of parenchymal organs that clinically are similar to digestive diseases. It enables detection of intraperitoneal tumour, to ascertain its relations with GT, assess thickening of the abdominal wall or bowel, detect metastases in the lymph nodes. Distension of abdominal walls and colon with water (saline) is a special method GT ultrasound.

Anatomical layers of walls of digestive organs can be observed at intracavitary,

transesophageal and endoscopic ultrasound unlike at CT. It is the advantage over other imaging methods in detecting of depth and extension of mural invasion.

MRI visualizes thickened wall of GT, but is worse than CT in spatial resolution.

Radionuclid methods of GT investigation. Its major area of investigation is estimation of motor-evacuation functions of a stomach. The information is represented as a series of scintigrams and the dynamic curves built from two regions of interest, usually, stomach and intestines.

Examination with the marked erythrocytes can reveal even minor gastrointestinal bleeding (0,1 ml / mines).

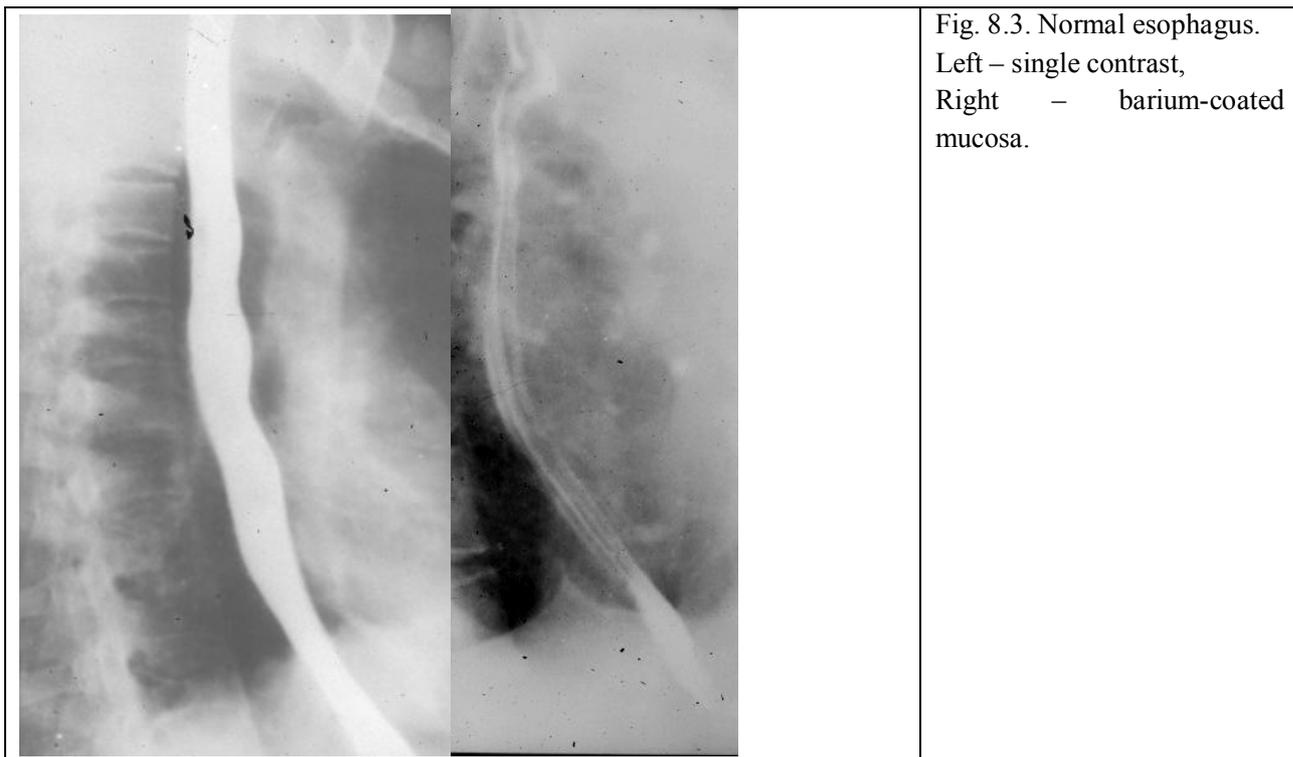
Radiological examination of esophagus. Diagnostics of esophageal diseases is complex. At present radiological and endoscopic methods prevail.

Indications for radiologic examination of esophagus:

1) dysphagia; 2) foreign body; 3) bleeding from the upper department of GT; 4) pain or compression mediastinal syndrome; 5) injury of mediastinal organs; 6) surgery or irradiation planning.

Examination will be carried out on an empty stomach. Survey fluoroscopy and radiography of thoracic and abdominal organs should be carried out for elimination of primary alterations in other organs. For the first stage of investigation standard fluid barium meal is used.

Radioanatomy. At examination of forms 2-4 longitudinal parallel folds along the entire esophagus can be revealed.



The width of esophagus is 2 cm on average; behind the screen the following physiological strictures can be revealed:

1. Cricopharyngeal (pharyngoesophageal sphincter);
2. Aortic, which is caused by pressure of aortic arch;
3. Bronchial is caused by impression of left primary bronchus;
4. Diaphragmal is caused by esophageal compressure by cruras of diaphragm;
5. Cardial is caused by sphincter of cardiac orifice.

Velocity of fluid barium meal passing through the esophagus is 2-3 seconds, of barium paste - about 6 seconds.

The pharynx and esophagus are examined in direct, oblique and lateral positions. In direct position of the patient the cervical department of an esophagus is seen most well. In the first oblique position optimal conditions for examination of a thoracal department of an esophagus, and in second oblique - a belly department of esophagus are created.

At esophageal examination the radiologist pays attention to:

- character of contrast mass passage;
- condition of contours and flexibility of walls along the whole length of esophagus.

In norm contours are smooth. The peristalsis is represented as surface wavy changes of esophageal contours.

At children during first 24 o'clock of their lives air fills entire GT, there is no air in GT after death.

Main radiological syndromes of diseases of alimentary canal:

1. Syndrome of organ dislocation.
2. Syndrome of alimentary canal narrowing:
 - a) diffuse narrowing;
 - б) local (limited) narrowing.
3. Syndrome of alimentary canal dilation:
 - a) diffuse dilation;
 - б) limited (local) dilation.
4. Syndrome of motor dysfunction of alimentary canal.
5. Syndrome of pathological modifications of a land forms of mucosa relief.

Radiological signs of foreign bodies and diseases of esophagus.

There are the following radiological signs *of foreign body in esophagus* (fig. 8.4.):

1. Shadow of a foreign body (contrast foreign bodies).
2. Filling defect (low-contrast foreign bodies).

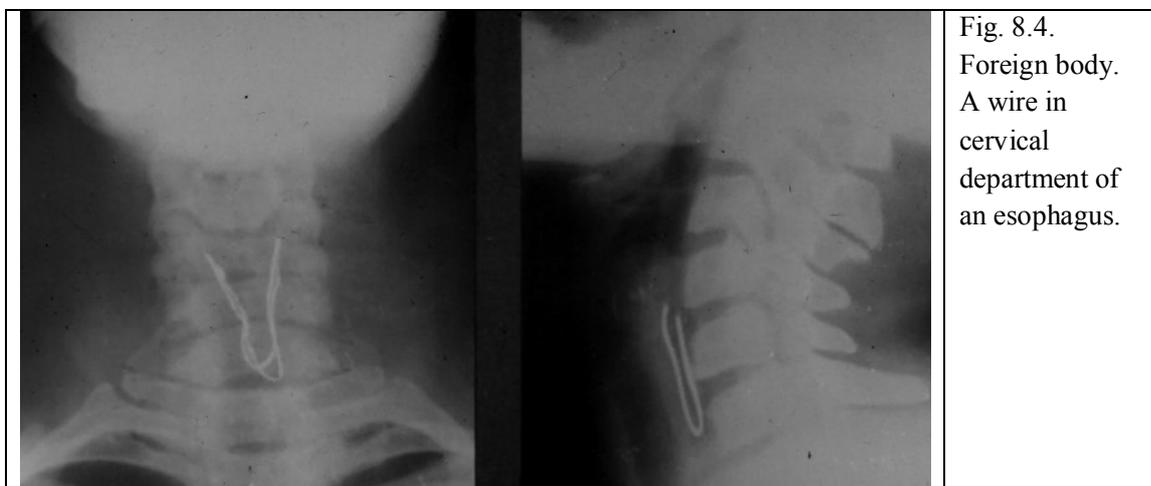


Fig. 8.4.
Foreign body.
A wire in
cervical
department of
an esophagus.

Diverticulums of esophagus are malformations (fig. 8.5). But there are also acquired diverticulums called traction. Local outpouching of esophageal shadow: if the shadow is spherical, it is pulsion diverticulum; and if the apex of shadow is pointed, it is typically for traction diverticulum.



Fig. 8.5. Diverticulum, esophageal.
Anterior outpouching (arrow) of the esophagus with signs of posterior displacement of the esophagus.

The achalasia is caused by spasm of cardiac orifice; relaxation of esophagus-gastric transition is disturbed. The radiological examination is the basis in diagnosing (fig.8.6). The sharp uniform growth of esophageal shadow, slow transition of barium into lower departments, symmetric funnel-shaped narrowing of esophagus with distinct contours is marked, which reminds of “a mouse tail“ and does not open at swallowing. Disturbance of motor function can be well demonstrated with marked colloid.

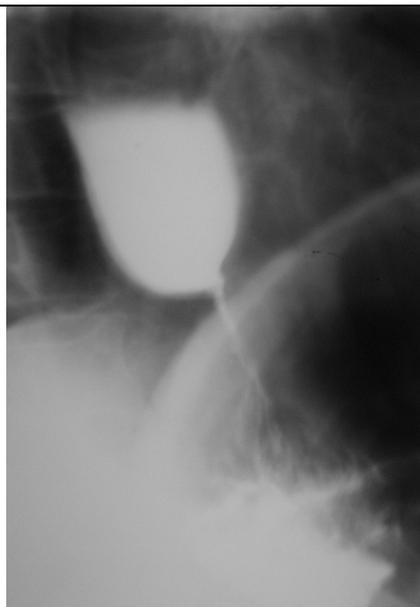


Fig. 8.6. Radiograph of lower thoracic and abdominal departments of an esophagus (single contrast). Symmetric cone-shaped narrowing of abdominal department of esophagus with symmetric smooth contours, supra-stenotic enlargement is marked. Achalasia of esophagus.

Cicatricial esophageal strictures are partial growth of shadow above narrowed area, usually found in region of physiological narrowings (fig. 8.7.). In differential diagnostics the fact of chemical burn is extremely important in anamnesis though some patients hide it.

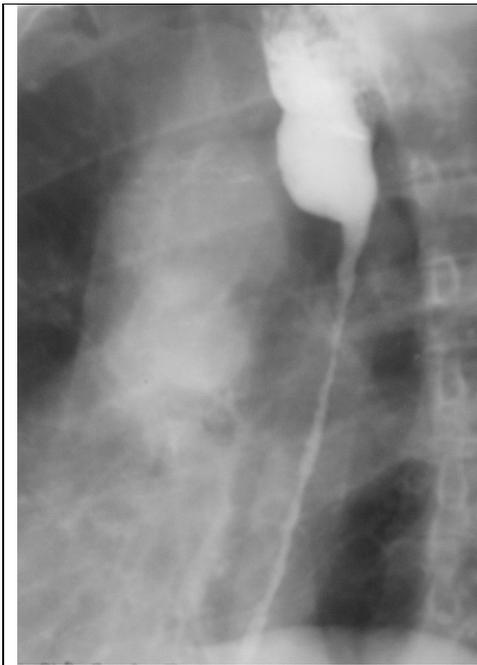


Fig. 8.7. Cicatricial esophageal stricture after chemical burn

The cancer of esophagus has the following radiological symptoms (fig.8.8): atypical mucosa relief, rigidity and narrowing of esophageal tube; filling defect and unevenness, wavy contours; filling defect and a niche; suprastenotic enlargement; regurgitation (reverse transport of contrast agent into higher departments). The most accurate methods for detecting stage of esophageal cancer are CT and endoscopic US, because the depth of involvement and enlargement of lymph nodes can be demonstrated.

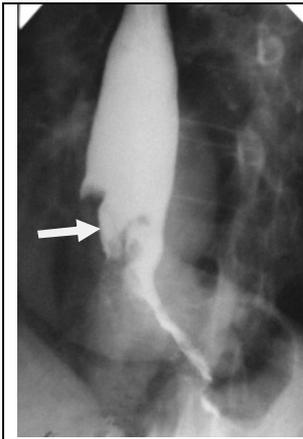


Fig. 8.8. Radiograph of an esophagus in left oblique projection. Boundary filling defect is detected beginning from the bottom third of thoracic department of esophagus with rough contours (arrow), passing in circular narrowing in abdominal department. Suprastenotic dilation of esophagus. Cancer of oesophagus.

Hernia of esophageal opening is the transition of organs of abdominal cavity or retroperitoneal space into thoracic cavity through natural foramens or through defects of diaphragm (fig.8.9.).

They are identified after detection of part of stomach or organ in thoracic cavity, above diaphragm. They present prolapse of stomach through esophageal foramen in posterior mediastinum. The main symptom of axial hernia is typical folds of mucous coat of stomach in the area of esophageal foramen of diaphragm which extend towards folds of subphrenic part of stomach. Another important symptom of axial hernia is shift of cardial department of stomach above the diaphragm. At acute hernia strangulation the X-ray usually is not carried out mainly because of grave condition of the patient. When strangulation of hernia of esophageal foramen is suspected, radiological examination should be carried out with the water-soluble contrast agent considering probable perforation of abdominal or esophageal wall.

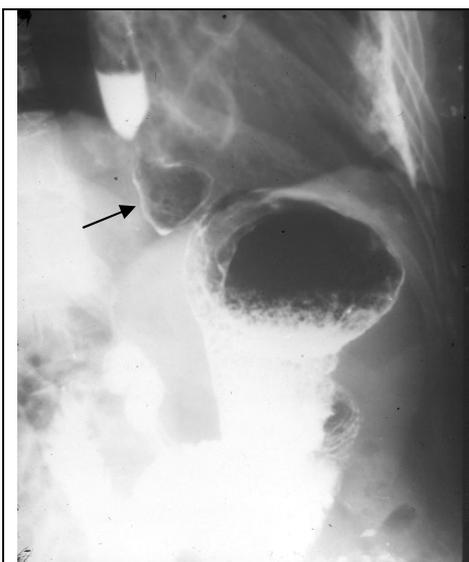


Fig. 8.9. Penetration of stomach through hiatus esophagus in posterior mediastinum (arrow).
Hernia of esophageal opening.

Radiological examination of stomach. Indications: complaints about gastric discomfort.

Technique of examination. For roentgenological examination special preparation of patients is necessary, including the following steps: the day before examination for lunch the patient eats twice less than usually at the expense of carbohydrates, but caloric value should be preserved. The supper should be also in usual time and it should include one glass of tea or coffee and a piece of bread and butter. Cleansing enemas are not necessary. In day of examination the patient should not eat, drink and especially smoke since nicotine produces abundant mucus discharge.

Examination of stomach begins after survey fluoroscopy of thoracic and abdominal cavities. Examination by the first stage:

1. Forms of folds of stomach. The folds can be: a) longitudinal - folds locating along lesser curvature; b) plexiform - short, sinuous, skew folds. The width of folds comprises 0,3-2,0 cm.

Single contrast of stomach (fig. 8.10.). The stomach can be shaped as a fishing hook or a horn.

Position of stomach. Three quarters of stomach are in the left half of abdominal cavity, one quarter - in the right one. The inferior contour of stomach shadow at men ranges at the level of pectinate line or 3 - 4 cm higher; at women it is 3 - 4 cm lower than this line.

Image of abdominal shadow. The shadow of the stomach filled with contrast mass is, as a rule, homogeneous. In its superior department gastric air bubble with distinct contours is usually visualized.

Contours of abdominal shadow. Contours of lesser curvature should be always even, and those of greater curvature, as a rule, should be notched, which is stipulated by transferring of mucosa folds from posterior wall to the anterior one.

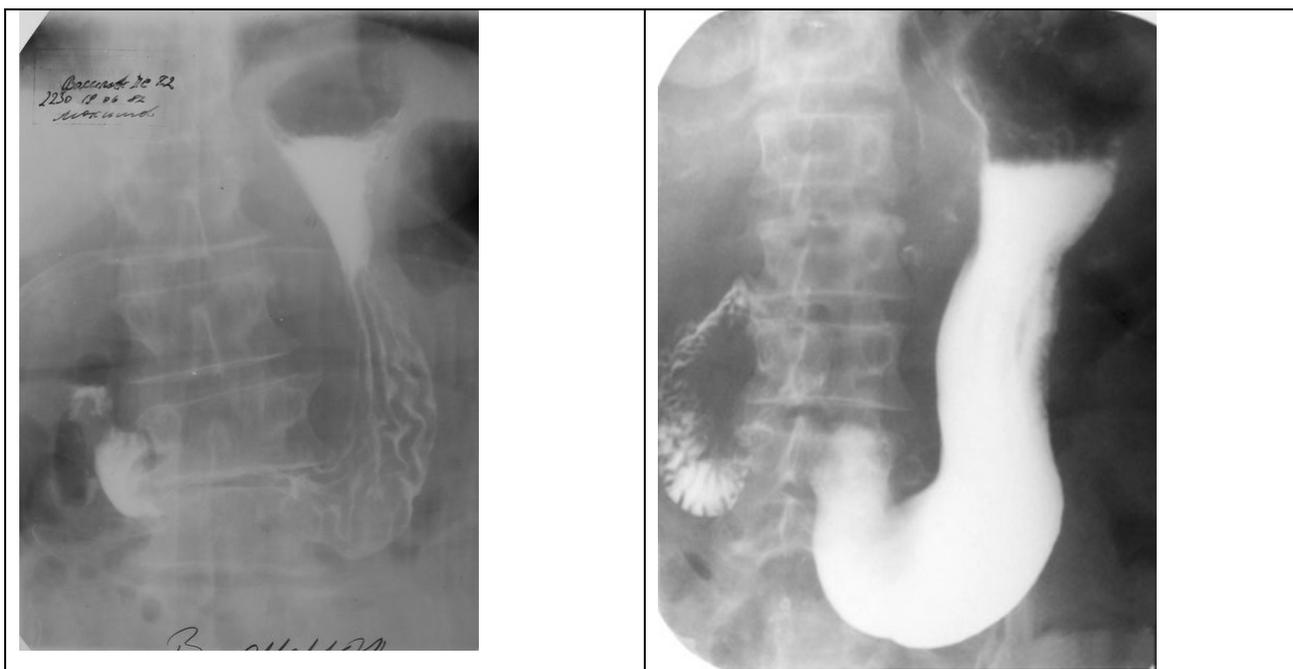


Fig. 8.10. Normal stomach. Left – barium-coated mucosa; right – single contrast.

Displaceability of stomach. The normal stomach easily displaces at deep abdominal breathing and it is revealed by changing of location, shapes and sizes. All this testifies preserved flexibility of walls and "loose" location in abdominal cavity.

Evacuation from stomach. The contrast mass from stomach, on the average, is evacuated in 1.5 - 2 hours; in 4 hours the stomach becomes completely free from contents. If barium meal is found in stomach in 6 - 8 hours, they speak about delayed evacuation; in 12 clocks there is a suspicion on pyloric stenosis; in 24 hours it testifies stenosis, 48-hour and longer presence of contrast mass in stomach means organic pyloric stenosis.

Stomach tone. Tone is a status of contracture abilities of muscular parts of organ, which defines sizes of cavity or its lumen. Walls of considerable part of alimentary canal close when empty, consequently the cavity of organ is represented as narrow chink. At food or barium meal transition the walls of the examined organ put up some resistance. The radiological rating of the tone of an organ comes to clearing up of how the cavitory organ is formed at its filling with contrast agent. In particular, normal (orthotonus), increased (hypersthenia), low (hypotonia) and lack of tone (atony) are distinguished.

Radiological indications of increased tone are: slow movement of contrast agent, reduced shadow of the investigated organ due to decrease of the cavity following the contracted status of a muscular wall.

Signs of the low tone, on the contrary, are connected with relaxation of muscles

of walls of the investigated organ. These factors consist in fast movement of the barium meal through the cavity, and augmentation of shadow of the investigated organ connected with dilating (increasing) of its sizes or of the lumen.

Peristalsis. Peristalsis of GT consists in contractions of circular muscles of the organ's wall which are rhythmic, and follow each other at equal intervals. The peristalsis of each organ is a part of those wavy contractions of shadow contours. The following notions are distinguished: 1) rhythm, 2) duration of single peristaltic wave, and 3) amplitude of peristaltic contractions.

Signs of normal stomach peristalsis:

1. Appearance Single rhythmic contractions in the upper part of the body, directed towards the pylorus.

2. Peristaltic waves follow one another with average intervals of 21 seconds. Closing and opening of the pylorus is caused by reflex action.

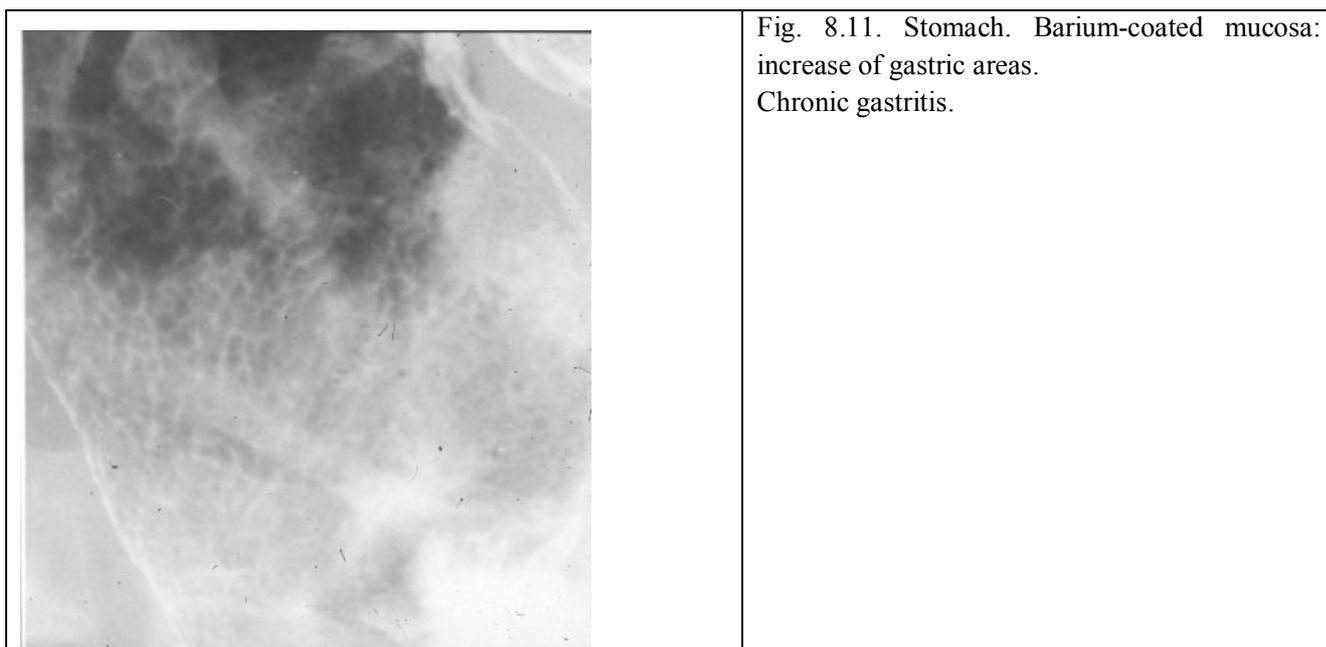
Duodenum is direct extension of pylorus the canal is. It is divided in 3 parts: upper horizontal, descending and lower horizontal. Upper part includes a bulb with 4 walls: front, back, medial, lateral. Contours of the bulb are distinct, even; commonly it is triangular-shaped with the base turned to stomach. The descending department is located to the right of column, goes parallel to its edge and forms small camber ectad, bending the head of pancreas. The inferior department of duodenum has an oblique direction to the right from below, to the left upwards, and then passes into flexura duodeno-jejunalis, situated behind the stomach at the level of the upper edge of 3 lumbar vertebra. Width of duodenum is 4 - 6 cm; in distant departments it is bigger. Bulb mucosa is extension of stomach mucosa and is represented by folds with longitudinal direction, converging at the bulb top.

Motor function of duodenum. It is expressed differently in different departments. The whole bulb usually contracts and as though squeezes out contrast agent in distal direction. However minor peristaltic walls contractions can be also observed. In the area of descending department wavy contractions, sometimes more expressed segmentations can be observed accompanying by tonic contraction of walls.

Radiological signs of stomach and duodenum diseases.

Chronic gastritis. In gastritis diagnosing the results of mucosa microrelief investigation (sizes and pattern of gastric areas) have crucial importance: (fig. 8.11). They can be revealed only on the enlargement images of stomach made at pressure on the anterior abdominal wall. At patients with superficial gastritis image is soft and uniform - areolas of irregular spherical or polygonal shape, 2-3 mm on the average in

diameter, separated one from another by very thin sulci of barium. Deep gastritis is characterized by uniform granular image with high roundish or oval areolas, from 2-3 up to 5 mm in diameter. At atrophic gastritis image of gastric areas is rugged, irregular and of different shapes and sizes (maximal diameter of alveoluses is more than 5 mm). Mucous membrane folds thicken as well. US at erosive gastritis reveals irregularities of contour of mucosa wall, its local thickening, symptome of "dissection" of abdominal wall which is connected with exudative inflammation of the wall.



Gastric and duodenal ulcers. Direct radiological symptoms:

1. Niche. 2. Convergence of mucosa folds. 3. Infiltration around ulcer. It is observed as protuberances on edges of niche or as narrowing of niche orifice. Niche is the result of ulceration of the organ's wall. Its depth of over 1-1,5 cm and its trilaminar contents (barium meal, fluid and air) can serve as indications of ulcer penetration (dissemination on adjacent organs). Depending on conditions of projections two types of ulcerous niche are distinguish: niche within contour and niche within relief.

Niche within contour (Haudek's niche) is identified at hard filling of stomach and presents local enlargement of shadows (fig.8.12).

Niche on mucosa folds looks like irregular-shaped spherical persistent spot corresponding to the accumulation of barium meal in ulcerous defect (fig. 8.13.). It can be revealed with the help of small amounts of contrast agents. Infiltrative swell within the contour is observed either as protuberances on edges of niche, or as

narrowing of niche orifice.

Infiltrative swell causes clarification on folds (ring-shaped).

Convergence of folds is an indication of cicatrization.

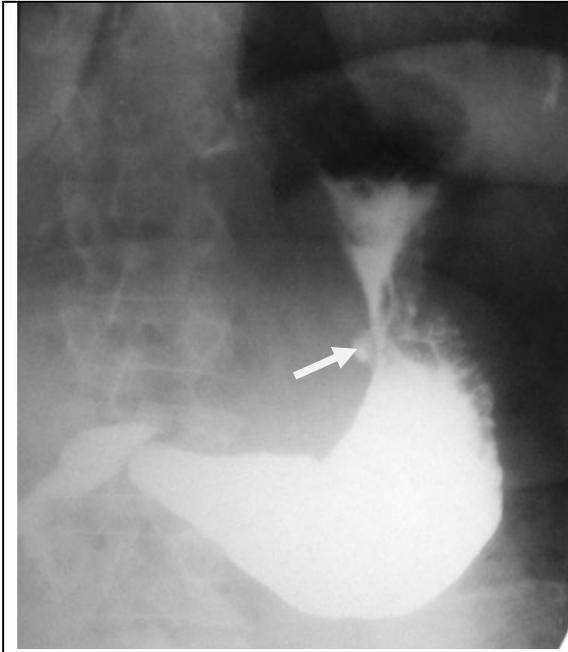


Fig. 8.12. Barium examination of the stomach shows a 1 cm-sized ulcer (arrow) on the lesser curvature of the stomach.

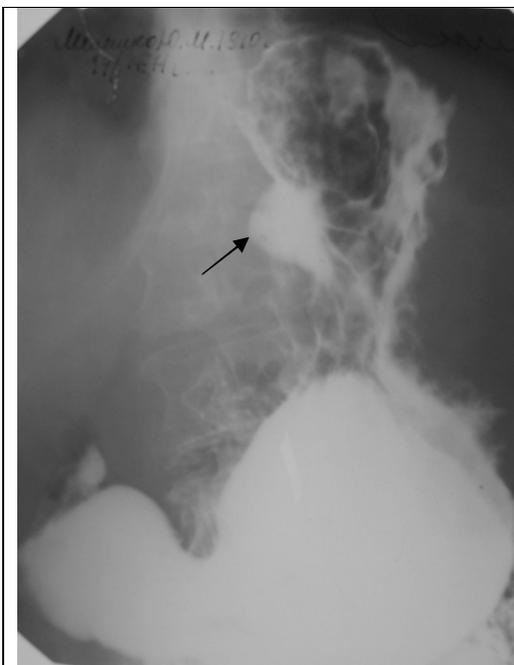


Fig. 8.13. Radiograph of stomach in direct projection with barium sulphate contrasting. On the lesser curvature a big niche is identified (arrow) in the top third of stomach with convergence of folds of mucous membrane. Gastric ulcer.

Functional symptoms: 1. Hypersecretion. 2. Hypertension or atony. 3.

Hyperperistalsis. 4. Limited spasm as penetration on the greater curvature, often corresponding to the level of ulceration on the opposite side. 5. The evacuation is accelerated or slowed down. 6. Local pain sensitivity.

Stomach cancer. Radiological signs:

- 1) infiltration, rectification and rigidity of mucosa folds;
- 2) destruction of mucosa folds, their substitution with tumoral masses;
- 3) rectification and irregularity of contour of organ's shadow;
- 4) strain and narrowing of organ's lumen;
- 5) filling defect, a niche;
- 6) lack of peristalsis and rigidity (immobility) of contour in affected region.

Non-uniform reduction of shadow of contrast agent in the cavity of investigated organ is an indication of presence of additional tissue (fig. 8.14).

Filling defect can be boundary (when barrier for contrast agent dissemination is located on the border) or central.

In the latter case multiaxial radiography should be carried out to reveal what wall, front or back, has the defect.

For malignant tumor the following aspects are typical:

- 1) boundary location of filling defect;
- 2) broad connection with wall;
- 3) rigid or corroded contours;
- 4) surrounding mucosa has atypical folds.

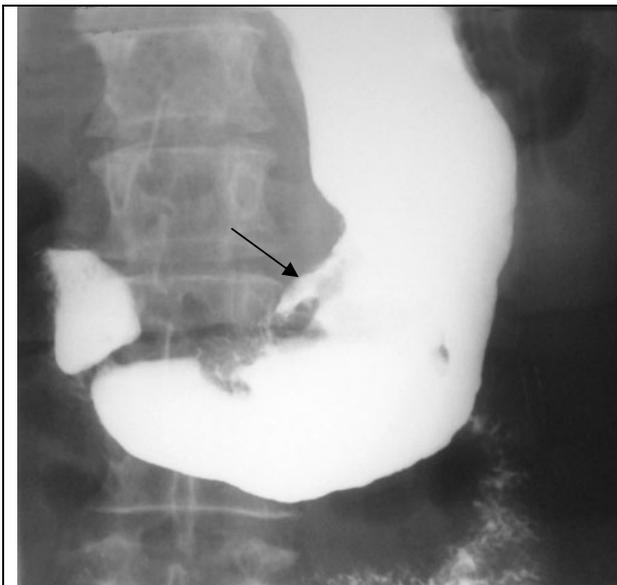
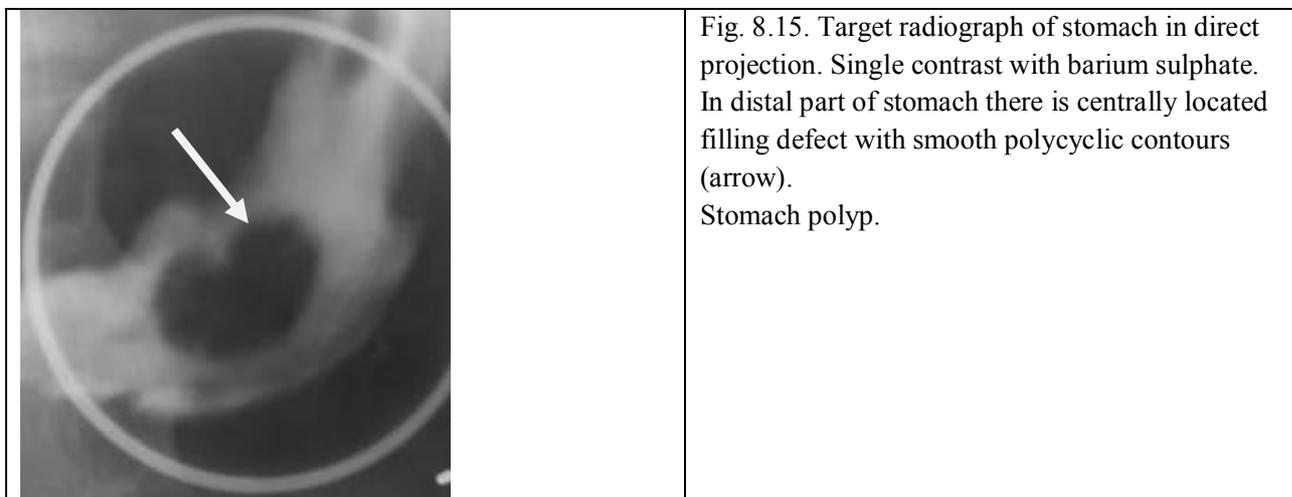


Fig. 8.14. Stomach cancer, polypoid form. Barium contrast study reveals rough lobulation of surface of polypoid tumour involving the lesser curvature of the stomach (arrow).

Polyps are benign tumours, characterized by central location of filling defects,

with smooth contours; they can be located on the leg and on the broad foot. Mucosa folds are not changed (fig. 8.15).



Thus CT and ultrasound have the following capabilities:

- They reveal intramural growth;
- visualize extragastral growth;
- reveal involvement of other organs and lymph nodes into the process.

Radiological examination of intestine.

Indications for radiological examination of intestine:

1. Chronic enteritises and colitises;
2. Prolonged constipation, diarrhea;
3. Enterorrhagia;
4. Intestinal obstruction;
5. Tumours;
6. Diverticulums.

Small intestine. Small intestine is better to study in 40 - 60 minutes after examination of stomach and duodenum. In most cases all this time small intestine is filled with contrast agent. Position, form of intestinal loops, their sizes (width), peristalsis and evacuation of contents are to be mentioned.

Loops of jejunum are located in the middle department of abdominal cavity, and ileum - in the lower right department, as well as in small pelvis. Intestinal loops can have small notches and it is caused by cross-section of folds. These folds in the relief phase form a specific fleecy image (fig.8.16). The width of loops varies about 2 cm. In small intestine dual movements are distinguished: peristaltic and pendulous.

The first are stipulated by function of circular musculation, second - by function of longitudinal musculation. The evacuation of contents from the upper department of small intestine takes place in 2 - 3 hours, from the inferior department - in 6 hours.

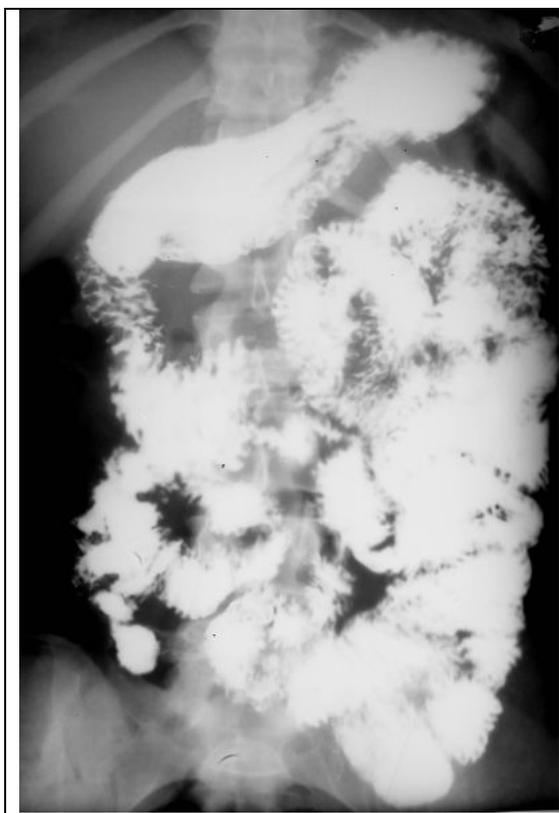


Fig. 8.16. Small intestine. Single contrast with barium sulfate.
Norm.

In 1 hour loops of a jejunum are filled, in 3 hours all contrast mass in ileum starts to move towards caecum, and in 7 - 8 hours the small intestine is completely emptied.

The most precise research technique of small intestine is X-ray examination after injection of barium directly into small intestine. Barium is introduced into small intestine directly through the intestinal tube in order to stretch the intestine maximally.

Radiological symptoms of diseases of small intestine.

Enteritises. Hypertonia and hyperkinesia of small intestine is typical for patients with severe enteritises. As a result of reinforced exudation, fermentation and disorders of adsorption, gas and minor fluid levels appear in small intestine. Deformation of mucosa relief is marked: folds are thickened non-uniformly, high, become even, quite often change their direction. Important indication of chronic enteritis are single small patches on the mucosa relief (grainy-nodular relief),

testifying focal edema of mucosa, occlusion and swelling of single segments, hypertrophy of solitary follicles.



Fig. 8.17. Small bowel. Single contrast with barium sulphate. Single small spherical formations on mucosa relief. Enteritis.

Regional enteritis (Crohn's disease). Can be of two forms. The first one is superficial non-sclerosing ileitis. The hyperplasia of lymphoid apparatus, similar pseudopolypous changes of mucosa is discovered in children and teenagers with edema of intestinal wall. It is revealed by formation of cellular image of mucosa relief and irregular intestinal contours. Intestine narrowing is not observed.

The second form is characterized by acute inflammatory infiltration, edema of all intestinal wall layers and ulcer formation on mucosa. Expansion of process on large intestine is possible. At an X-ray examination irregular narrowing and obstruction as well as enteroenteric fistulas and enterocutaneous fistulas can be observed. The mucosa relief becomes acinose, polypiform, ulcers cause niche sign (fig. 8.17.).



Fig. 8.17. Terminal ileal Crohn's disease. Note long, narrowed "string" like terminal ileum which has shallow ulcers.

Ultrasonic and CT allow in addition to a X-ray inspection at diseases of a small bowel:

- to visualize a thickening wall of an intestine;
- to spot an expansion extraintestinal lesions;
- to reveal complications: fistulas, abscesses.

Cancer of small intestine. X-ray investigation reveals filling defect of irregular shape and rough contours, narrowing of lumen. The deformation of mucosa relief in the region of edema is detected, break of mucosa folds. The peristalsis in the area of the swelling is not detected. At CT the thickening of intestinal wall and of metastasises into lymph nodes is visualized.

Radiological examination of large intestine. The basic research technique of large intestine is irrigoscopy - examination of colon with preliminary injection of contrast agent through the rectum.

Examination of colon after introduction of baric suspension per os should be carried out only to study its function status (emptying), and also at intentional examination of terminal department of small intestine together with caecum (ileocecal angle).

Proctosigmoidoscopy should be carried out beforehand.

Preparation of patients. Before examination patients do not have supper. In the evening they are given two purgative enemas with pure water with an interval of 1 hour. In the morning 2 hours prior to examination the patient is given two cleansing enemas with an interval of 30 min.

Contrast agents. Barium meal is prepared at the rate of 1 part of barium sulfate per 4 parts of water with adding of 4,0 g Tanninum per 1 litre of contrast agent. To fill

rectum and colon 600-800 ml of a contrast agent are commonly sufficient.

Procedure of examination. The enema with barium is introduced gradually under monitoring, until the contrast mass reaches caecum and fills it. Sizes, positions of loops, condition of contours, and progression of contrast mass are investigated. Suspicious fields (changes) should be registered on the enlargement film. When the entire large intestine is filled one survey image on film 30 × 40 cm is made, and the first investigation phase is considered finished (fig. 8.18).



Fig. 8.18. The enema with barium. Single contrast. Sizes, positions of loops, condition of contours, progression of contrast mass.

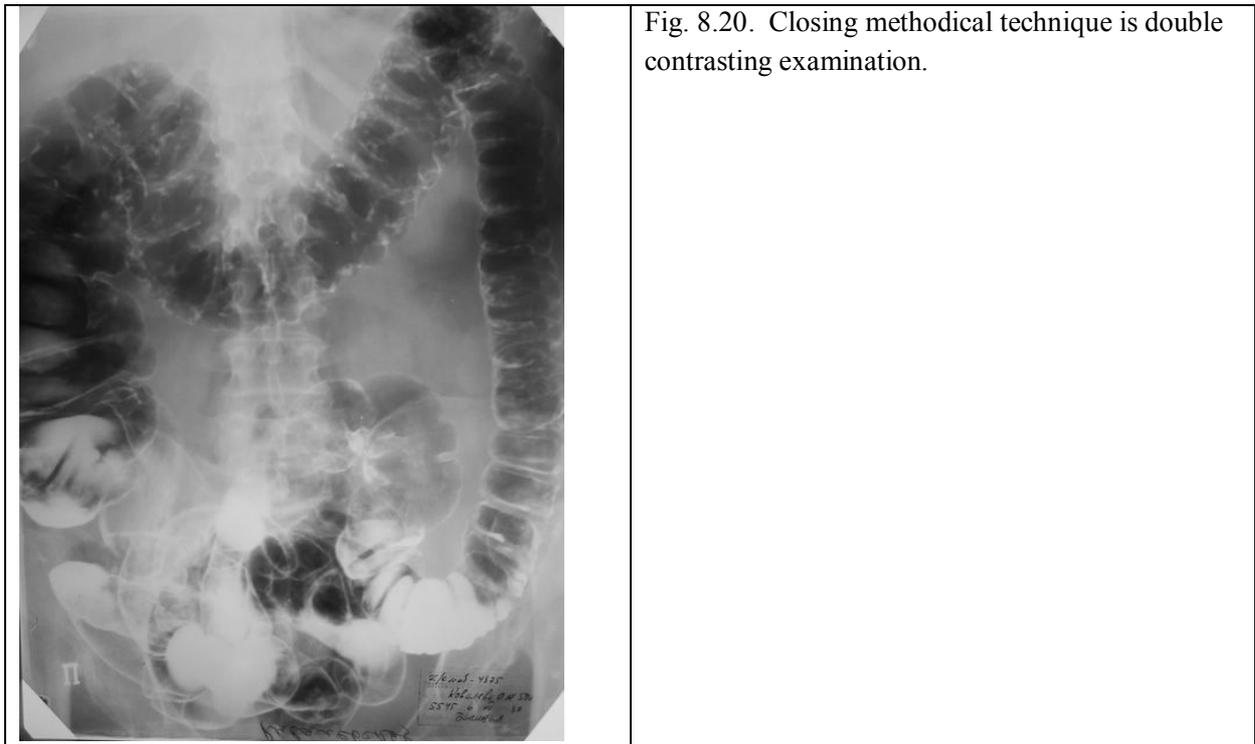


Fig. 8.19. The second stage - examination of mucosa relief is carried out after bowel emptying.

The second stage – examination of mucosa relief is carried out after bowel emptying (fig. 8.19). Under screen monitoring in conditions of dosed compression mucosa folds of all intestinal departments are investigated (target images of suspicious fields are obligatory). Closing methodical technique is examination by double contrasting which is rather important at suspicion of neoplasm. Under screen monitoring inflation of large intestine is carried out; changed and suspicious fields are subject to radiography (target imaging), and the last diagnostic technique is survey imaging on 30 × 40 cm film of intestinal all loops in status of double contrasting (fig. 8.20).

At present contrast enema with double contrasting without hard filling is

recommended.



Contraindications to irrigoscopy:

- toxic dilation of intestine;
- suspicion of perforation;
- deep biopsy carried out within last week before examination (superficial biopsy of mucosa is not a contraindication).

Additional contraindications to contrast enema with double contrasting:

- intestinal obstruction;
- severe acute colitis;
- technical difficulties (not-mobile patient).

In rectum contours, as a rule, are even. The width of lumen is bigger on the right. Haustration is a criteria of assessment of colon tone. At high tone haustras are high, narrow and frequent. At low tone the intestine is wider, haustration is barely marked and visible.

Radiological signs of diseases of large intestine.

The cancer of large intestine can be identified by filling defect (boundary or central), atypical mucosa relief change and defect on folds, intestine narrowing, irregularity of contours, dilation of intestine higher and lower than the tumour affected fragment. Ultrasound and CT play the leading part in differentiation of

cancer of large intestine from its invasion from the outside at cancer of bile and urinary bladder, prostate gland and female generative organs (fig. 8.21).

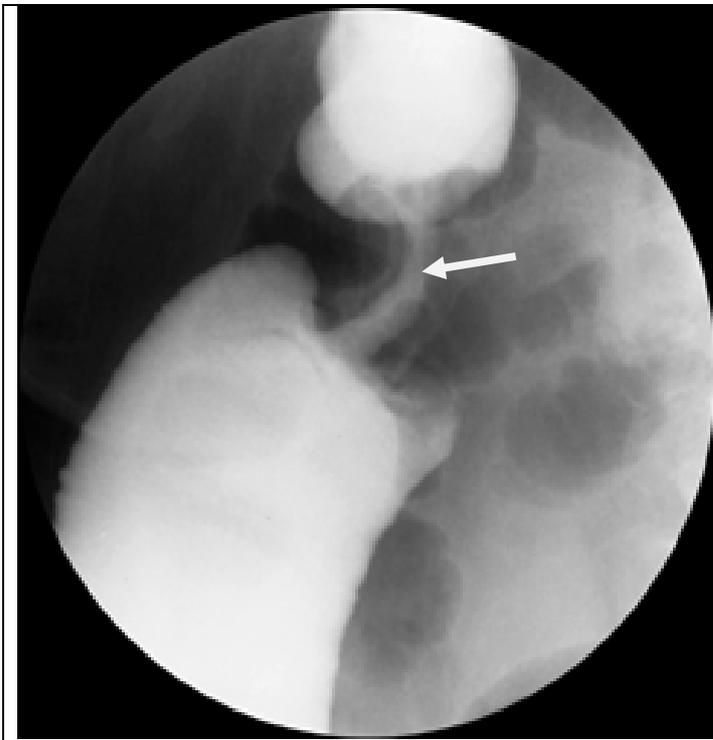


Fig. 8.21. Barium study demonstrating narrowing of the lumen of the proximal part of sigmoid colon with overhanging edges (arrow).
The cancer of the large intestine.

Diverticulosis of large intestine is local augmentation of intestinal lumen as a round shadow. Usually multiple (fig. 8.22). Can be complicated by inflammation, bleeding, perforation. Ultrasound visualizes the thickened intestinal wall, abscesses, fistulas. CT visualizes thickening of wall (more often than ultrasound), infiltration of peridiverticulitis adipose tissue, perienteric abscesses, fistulas.



Fig. 8.22. Double contrast barium enema. Dolichosigmoideum. Numerous diverticulae of the sigmoid and the descending colon.

Nonspecific ulcerous colitis. Rectum, left half of large intestine is affected more often; sometimes total affection takes place.

Main radiological indications: thickened folds with wrong direction, indistinct contours of large intestine, cellular image of mucosa, healthy parts of mucosa relief alternating with the affected ones creating a pattern of “tortoise shell” (fig. 8.23).



Fig. 8.23. Barium enema, revealing numerous superficial and deep ulcerations of the rectosigmoid, visible as barium outpouchings of various size and shape.

Tuberculosis of large intestine. Ileocecal region is the main localization. Arises for the second time as a result of lymphogenous and hematogenous diffusion at pulmonary tuberculosis. Localization in the terminal department of ileal intestine and in proximal departments of large intestine is typical. Disorders of tone in the form of atonic and spasmodic changes, considerable atypical mucosa relief differentiates it from tumoral atypical malignant relief. Key factors of difference of this process from tumoral is its typical localization with involvement of terminal department of ileal intestine, pulmonary tuberculosis.

X-ray indications at acute abdominal catastrophes.

Radiological signs of perforated stomach ulcer (fig. 8.24):

- gas accumulation in the abdominal cavity (pneumoperitoneum – chest and abdominal films visualizes air below the diafragm);
 - high position of the left cupula of diaphragm and limitation of its motility;
 - (in several hours) signs of paralytic bowel obstruction, connected with developing peritonitis: expressed meteorism, sometimes presence of separate gas bladders with horizontal fluid levels.

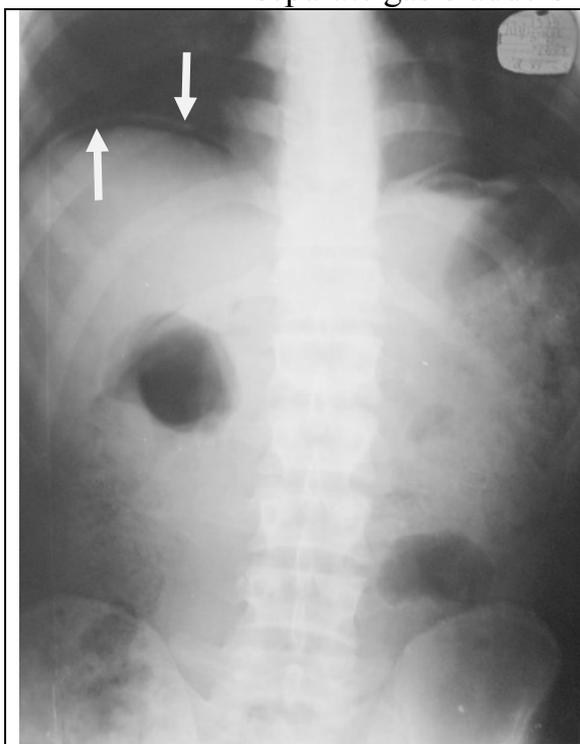


Fig. 8.24. gas accumulation in abdominal cavity (pneumoperitoneum – chest and abdominal films visualizes air below the diafragm). Pneumoperitoneum.

Acute intestine obstruction: on survey image of abdomen cavity a lot of gas bladders with horizontal fluid level are discovered (fig. 8.25). More distantly places of obstruction of intestinal loop are dissipated and do not contain any gas and fluid. This

indication enables to distinguish mechanical obstruction of intestine from the dynamic one. At dynamic obstruction the peristalsis of intestine is not observed either.

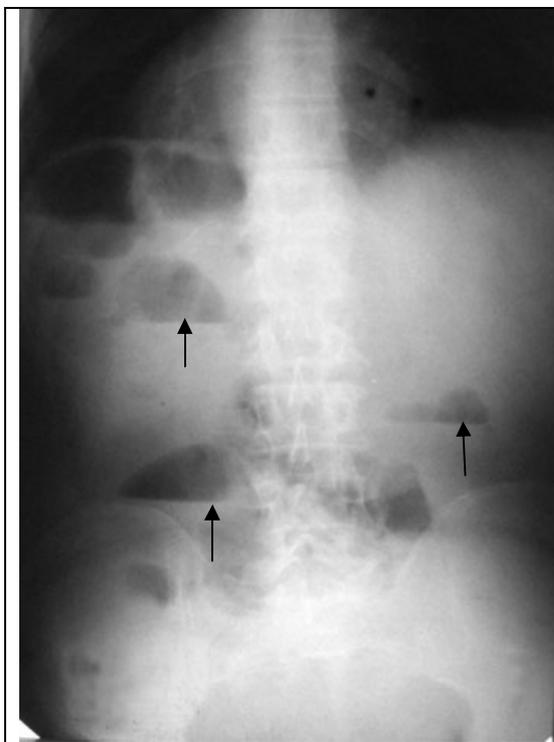


Fig. 8.25. Abdominal plain film. Air-fluid levels in patients with small bowel obstruction. Note the dilatation of the air-filled loops.

8.2. Radiological examination of liver and bile passages

Primary method of visualization is ultrasound.

Ultrasound investigation of liver and bile passages

Indications to ultrasound of liver:

1. Hepatomegaly; purpose is to define sizes, form, structure of parenchyma, condition of intrahepatic vessels and determine the cause of this pathology.
2. Chronic diffuse diseases; the purpose is to determine volume of affection, identify type of disease.
3. Suspicion of tumour of liver; demonstration of changed of liver form and its echostructure, definition of precise localization of tumour for puncture.
4. Suspicion of cyst; determination of precise cyst localization.
5. Jaundice - assessment of the nature of disease, visualization of enlarged bile ducts, gallbladder, determination of pathological changes in pancreas, in parenchyma.
6. Trauma and posttraumatic conditions; visualization of place of blood accumulation; assessment of condition of posttraumatic cicatrice, as well as volume of affection of the liver.

7. Decompensated heart diseases causing overload of its right departments - with the purpose of assessment of an extent of parenchyma injury and assessment of condition of hepatic veins.

8. Acute and chronic cholecystitis.

9. Cholelithiasis (formation of gallstones).

10. Cancer of bile bladder and bile ducts.

In general, clinical signs of possible liver and bile ducts damage are the indications to ultrasound.

Preparation for ultrasound of liver: three-day diet and intake of the pharmaceuticals decreasing meteorism. If the patient has constipations, on day prior to examination it is necessary to give laxative in the evening or to make cleansing enema.

Sonographic criteria of normal liver condition (fig. 8.26):

1. Distinct contour of liver borders.

2. Homogeneous parenchyma with low-amplitude echo signals.

3. Visualization of portal vein with its branchings of II and III order, hepatic veins and their inflow into inferior vena cava.

4. In norm intrahepatic bile ducts are not visible, as well as intrahepatic branches of hepatic arteria.



Fig. 8.26. Normal liver ultrasound.

The height of right hepatic lobe by 5 years is 4 cm, by 12 years it is doubled, by 15 years - 10 cm.

Ultrasound of gallbladder determines: 1) position; 2) form; 3) condition of walls; 4) content; 5) function of gallbladder. Gallbladder in norm has anechogenic contents, wall thickness of 2-3 mm, average sizes: length - 7-10 cm (less than 13 cm), diameter - 3 cm (less than 4 cm) (fig. 8.27). On empty stomach bile bladder rarely exceeds the sizes of 4 × 10 cm.

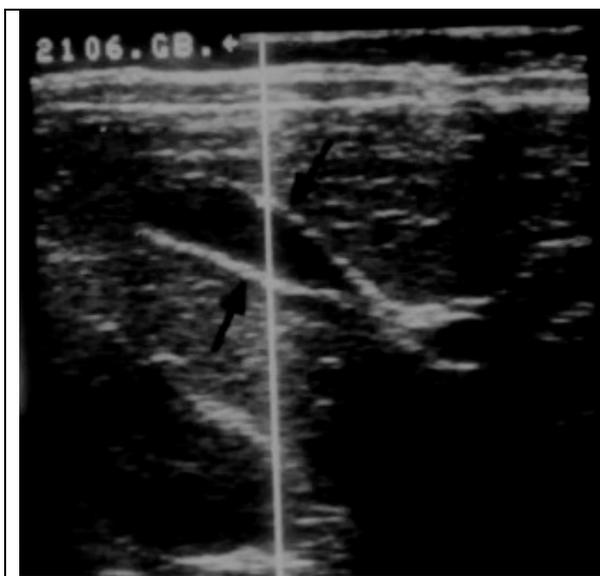


Fig. 8.27. Normal gallbladder ultrasound (arrows).

Visualization of small bile ducts inside liver is an indication of pathological process. At 95 % of patients the diameter of normal common bile duct is 0,4 cm and fewer.

Computed tomography of abdomen and retroperitoneal space. Indications:

- I. 1. Trauma of abdomen with suspicion of internal injury (liver, kidney).
2. Focal and diffuse liver diseases:
 - a) Cysts of liver (congenital and parasitogenic);
 - b) Primary tumours of liver;
 - c) Metastases;
 - d) Abscesses of liver (of various etiology);
 - e) Cirrhosis of liver;
 - f) Adipose degeneration.
- II. 4. Diseases of gallbladder:
 - a) Acute cholecystitis (empyema of gallbladder);
 - b) Suspicion of chronic calculous cholecystitis at nonfunctioning gallbladder and doubtful data of ultrasound and cholecystography;
 - c) Cancer of gallbladder;
 - d) Choledocholithiasis;

e) Hemobily.

III. 5. Obstructive jaundice.

IV.6. Diseases of a pancreas:

a) Acute pancreatitis (pancreatonecrosis);

b) Cyst of pancreas;

c) Chronic pancreatitis;

d) Tumors of pancreas.

In norm the liver has smooth distinct contours on tomogram. Its lobes separated by incisures can be easily identified. Parenchyma structure is homogeneous.

Intrahepatic bile passages with diameter of 1-2 mm with the help of this method cannot be visualized. Anhepatic, common bile ducts are visible without injection of contrast agents temporary, are visualized after contrasting.

Bile ducts on tomogram in norm are not visible; enlarged ducts because of low density are differentiated clearly on cuts without contrasting. CT enables to assess not only the sizes and shape of liver, but also location of surrounding organs.

Cholecystography. Bile ducts on common images are not displayed. Artificial contrasting is used. Contrast agent is introduced by 3-6 g. Medicine is taken by small portions during 20 min. and taken with alkaline water or sweet tea. Then the food is completely excluded, but drinking of mineral water and sweet tea is allowed. The fluoroscopy and radiography in 13-14 hours after introduction of contrast agent is carried out. Gallbladder to the right of center line: length is 5-8 cm, and diameter is 2,5-3,5 cm. Contours are distinct, arched, the shadow is intensive and homogeneous.

Indications: cholelithiasis, dyskinesia of gallbladder. Contraindications: idiosyncrasy to iodide drugs, thyrotoxicosis, cardiovascular decompensation, renal and hepatic failure.

Cholegraphy. Hepatotropic iodine contrast agent is introduced intravenously. Bilignostum, Biligrafinum are used. Immediately before the examination 1 - 2 ml of Bilignostum are introduced intravenously. At no response within 2-3 minutes, not taking out a needle from vein, all required amount of drug 30-40 ml of 20 % of solution of Bilignostum is injected. In 10-15 minutes after injection bile ducts (common bile duct, hepatic and gallbladder ducts and their branchings) are contrasted. In 50 - 60 minutes the shadow of bile ducts becomes less intensive, and then it disappears. At the same time the shadow of gallbladder gradually increases and reaches its maximal intensity in 1,5-2 hours after injection of Bilignostum. Indications: exacerbation of chronic cholecystitis, cloelithiasis, condition after a cholecystectomy, negative results of cholecystography.

Contraindications: idiosyncrasy to iodine, severe diseases of liver, kidney, thyroid gland; decompensation of cardiac activity.

The role of cholecystography and cholegraphy essentially decreased in connection with development of other methods of visualization, first of all - ultrasound. Cholecystography and cholegraphy are carried out only when ultrasound results are doubtful.

Endoscopic retrograde cholangiopancreatography (ERCP) is carried out by cannulation of major duodenal papilla with the subsequent injection of the water-soluble iodine contrast agent into bile ducts. The procedure enables to estimate the condition of duodenal papilla, bile ducts and pancreatic duct. Indications: differential diagnosis of mechanical and hepatic icteruses. Contraindication: intolerance of iodide drugs, breaking of coagulating system of blood, acute pancreatitis, acute cholangitis and cholecystitis, common grave condition of the patient, contraindication to introduction of endoscope.

Percutaneous transhepatic cholangiography (PTC). Indications: differential diagnosis of mechanical and hepatic icteruses, clarification of localization, nature and character of occlusion of bile ducts.

Contraindications: intolerance to iodide drugs, hemorrhagic diathesis, acute breaking of coagulating system of blood, echinococcus or polycystosis of liver. As a contrast agent 50 % solution of Hypaque is applied. Complications: bleedings, outflow of bile in abdominal cavity, shock.

Operative cholangiography. At this method contrast agent is introduced directly into bile ducts during operation (fig. 8.28). Indications: stones in bile ducts or suspicion of them, dilating bile ducts, augmentation of the head of pancreas. Contraindications: no absolute contraindications, among relative ones - acute cholangitis.

On cholegrams width of shadow of normal common bile duct comprises up to 0,7 cm, on cholangiograms normal common bile duct can reach 1,5 cm.

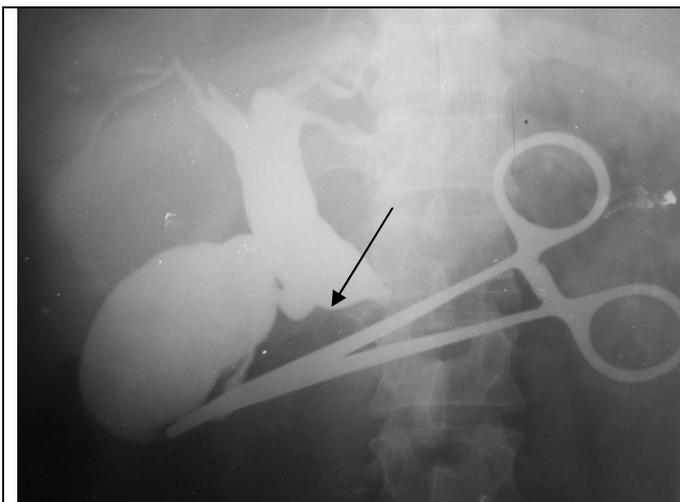


Fig. 8.28. Operational cholangiography. The contrast agent is introduced into bile ducts. Massive dilatation of the common bile duct and hepatic ducts, gallbladder. Obstruction of common bile duct, with rough contours (arrow). Contrast agent does not reach the duodenum. Cancer of the common bile duct.

Angiography. For study of bloodflow and condition of blood vessels, which supply liver, selective catheterization of truncus coeliacus (arteriography) became the most popular. Thus analysis of the image of arteriography is grounded on study of three serial phases: arterial, parenchymatous and venous. Data obtained can enable to diagnose affection of hepatic vascular system and disorders in its hemodynamics as well as malformations of liver and character of focal lesions can be specified.

Radionuclid methods of liver visualization. The study of function state of polygonal cells of liver is possible at *dynamic scintigraphy*. Dynamic scintigraphy with usage of the ^{99m}Tc -labeled imidodiacetic acid (hepatotropic derivants) provides determination of the parameters describing secretory and excretory functions of liver, patency of bile ducts, accumulative and motorial functions of gallbladder, basic anatomical parameters (position, shape, sizes) of liver, gallbladder and intestines.

A number of scintigrams enable to assess absorption and excretory functions of liver visually, time and degree of gallbladder contrasting, motor function of gallbladder, patency of bile ducts, some anatomy-topographical peculiarities of liver and gallbladder. The obtained information is reproduced on the display of the computer; and four zones of interest are distinguished: heart, liver, gallbladder, small intestine. After choosing these zones, the information is integrated and activity curve is made - time from the chosen zones of interest.

Mechanical icterus causes substantial growth of time of maximal accumulation of drug in liver, clearance of blood does not change significantly, and drug is practically not removed into the small intestine.

Parenchymatous icterus is accompanied by abrupt disorders in functional state of liver with the most typical decrease of parameters of blood clearance and retardation of liver clearing of injected drug.

Concentrational function of gallbladder is calculated under the attitude of count rate in the gallbladder region to count rate in the liver region.

Static scintigraphy of liver. Main diagnostic problems of static scintigraphy of liver are:

- anatomical peculiarities of organ (sizes, shape, position relative to other anatomical structures);
- character of lesion (diffuse, focal);
- gravity of lesion and syndrome of portal hypertension (acute and chronic hepatitis, liver cirrhosis, etc.)
- focal lesion of liver.

Adequate solutions of the problems mentioned above are made with methods of scintigraphy with usage of radioactive colloidal drugs marked ^{198}Au , $^{99\text{m}}\text{Tc}$, $^{113\text{m}}\text{In}$ which create high concentration in liver.

Colloid particles stay for a long time in the system of mononuclear phagocytes of liver therefore it is possible to conduct repetitive examination in various regimes and projections. At liver cirrhosis examination with radiocolloids provides with additional information on the state of liver.

Principle of analysis of the obtained information at static scintigraphy of liver. Position, shape, distribution in liver and spleen, staining and degree of colloid accumulation, character of contours and presence of typical incisures, character of colloid allocation, presence of the loci of no radiocolloid allocation, degree of anhepatic accumulations of radioactive nuclide.

Scintigraphy liver imaging (fig.8.29). Liver imaging in direct projection has a triangle shape with its base turned towards the abdominal cavity. Contours of organ are distinct. Relative metrical values are used. Among them: ratio of maximal heights of left and right lobes (in norm no more than 20 %). It is necessary to emphasize, that the edge of the liver image can be visualized on half-clavicle lines on 0,5-2 cm, on line of xiphoid process 2-4 cm below marked costal margin.



Fig. 8.29. Static scintigraphy of liver.
Normal distribution of ^{99m}Tc -labeled colloid in liver and spleen.

The image of spleen in direct projection is always visualized on scintigram. Accumulation of radiocolloid by a spleen at gauging in a front projection does not exceed 4-5 % concerning a common radioactivity of a liver and a spleen. The bone marrow in norm is not visualized.

The scintigraphy of a liver is second to other methods of visualization in diagnostics of focal lesions of liver (locuses of lesion with sizes not less than 3 cm are detected).

Signs of local decrease or lack of radiocolloid accumulation are typical. In some cases it is more informative than other methods of visualization (for example, malignant lymphatic system diseases).

Thus, radionuclid examination of liver and bile ducts yields very important diagnostic information on function and anatomical-topographical state of liver, intrahepatic bile ducts, gallbladder, common bile duct.

MRI. Capabilities of MRI are similar with those of CT, but at MRI image can be obtained in all shots, it is possible to obtain the image of hepatic vessels (MR - angiography), bile ducts and pancreatic ducts (MR - cholangiography).

Radiological symptoms of diseases of liver.

Hepatitis. Decrease of liver echogenicity is typical for severe cases of acute hepatitis, elements of portal vein are more bright against this background, hepatomegaly is detected. At chronic hepatitises echogenicity is often increased (fig. 8.30).

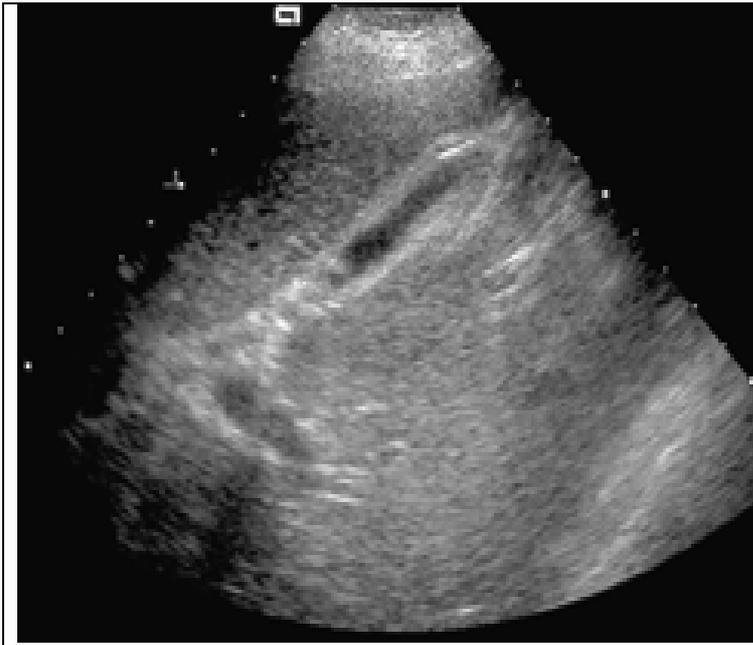


Fig. 8.30. Gallbladder affected by acute hepatitis.
 Ultrasound examination, demonstrating small volume of gallbladder which reveals markedly thickened wall.

As a rule, at diffuse lesions of liver radionuclid technologies have more diagnostic capabilities than other imaging methods (fig. 8.31).

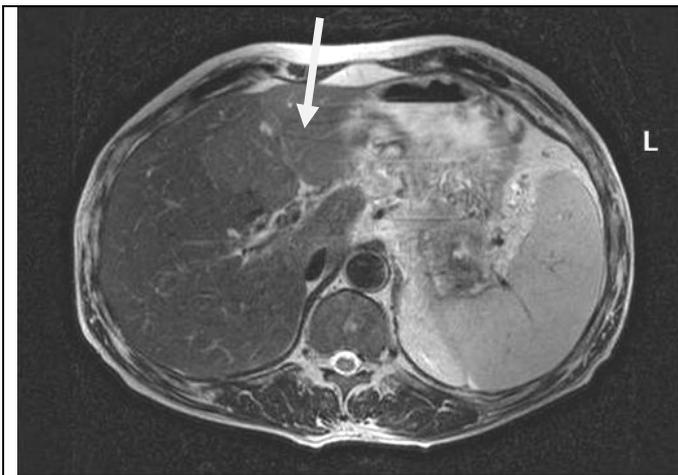


Fig. 8.31. MRI of liver. T2-WI. Inflammation with more intensive signal (arrow) is defined in liver tissue.
 Acute hepatitis.

The chronic hepatitis - distribution of radiocolloid has irregular character at 50-60 % of patients. One of indications is shift of the area of maximal radiocolloid accumulation from the central right lobe. At 50-60 % of patients the sizes of lien increase, accumulation of radiocolloid increases (10-15 %), and at active chronic hepatitis radiocolloid accumulation exceeds 15% in 30 % of cases (fig. 8.32).

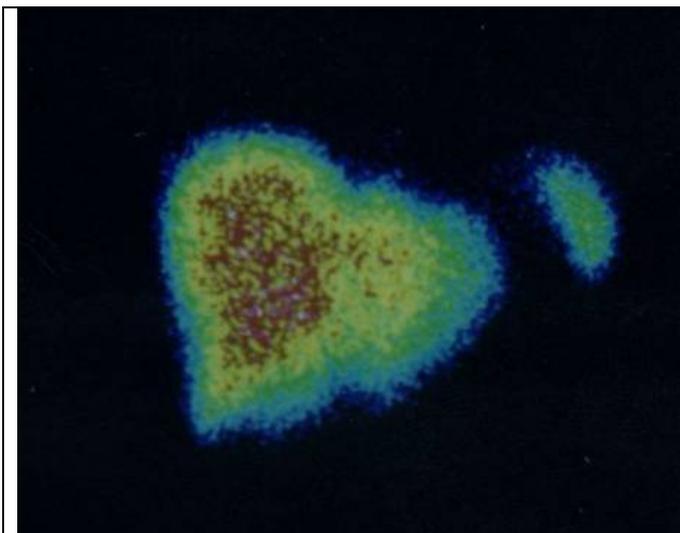


Fig. 8.32. Static scintigraphy of liver with ^{99m}Tc -tehnefit (^{99m}Tc -labeled colloid). Diffusion growth of liver, decrease in ^{99m}Tc -labeled colloid accumulation, mainly in the field of the left lobe. Increase of ^{99m}Tc -labeled colloid capture by spleen (more than 10 %). Diffusion changes of liver parenchyma, typical for chronic hepatitis.

Liver cirrhosis (fig.8.34.). Ultrasound reveals changing of liver sizes at cirrhosis, roughness of contours of the organ, increase and heterogeneity of liver echogenicity, augmentation of lien, dilation of portal vein (norm - less than 1,5 cm), splenic vein (norm - less than 1,0 cm), ascites (fig. 8.33). High performance of ultrasound at ascites diagnostics should be mentioned. Minimum quantity of fluid that can be revealed by ultrasound is 50 mm. In this respect ultrasound is second to laparoscopy.

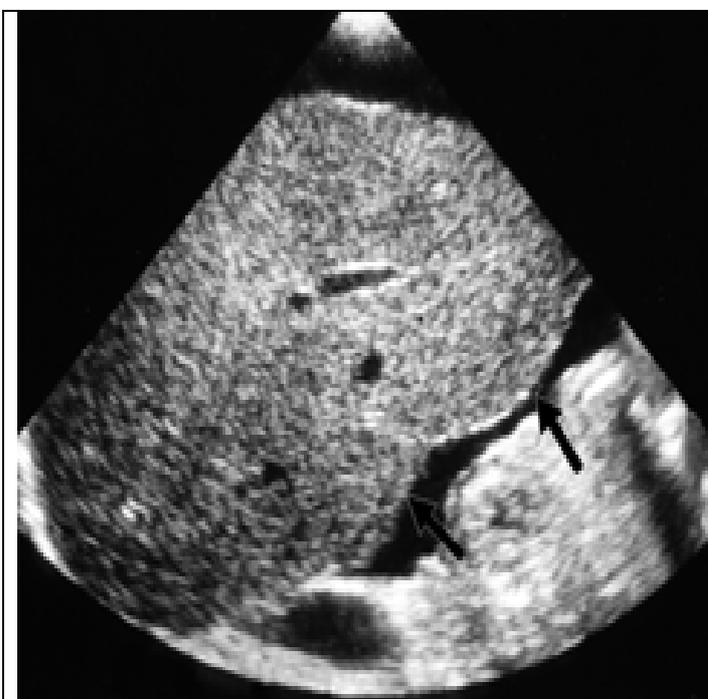


Fig8.33. Ultrasound examination. The irregularity of the liver contour (arrows) is clearly visible because of the presence of a considerable amount of ascites. Cirrhosis of liver.

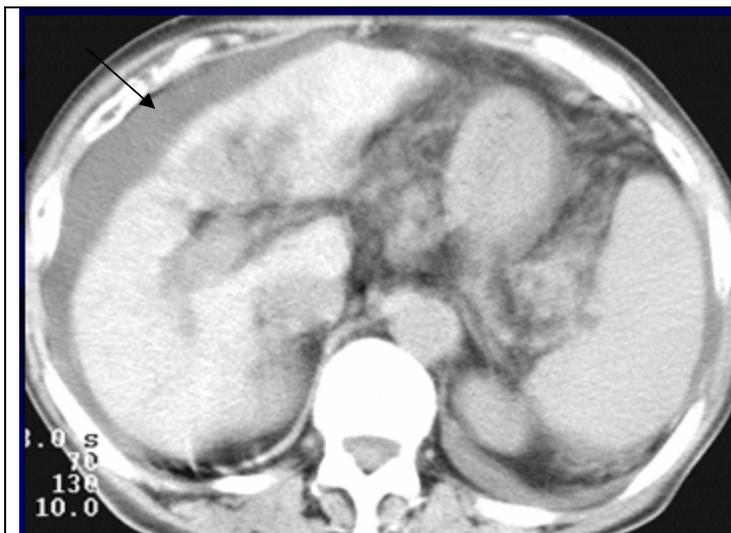


Fig. 8.34. CT also shows heterogeneity of hepatic frame, roughness of contours, presence of ascites (arrow).
Cirrhosis of liver

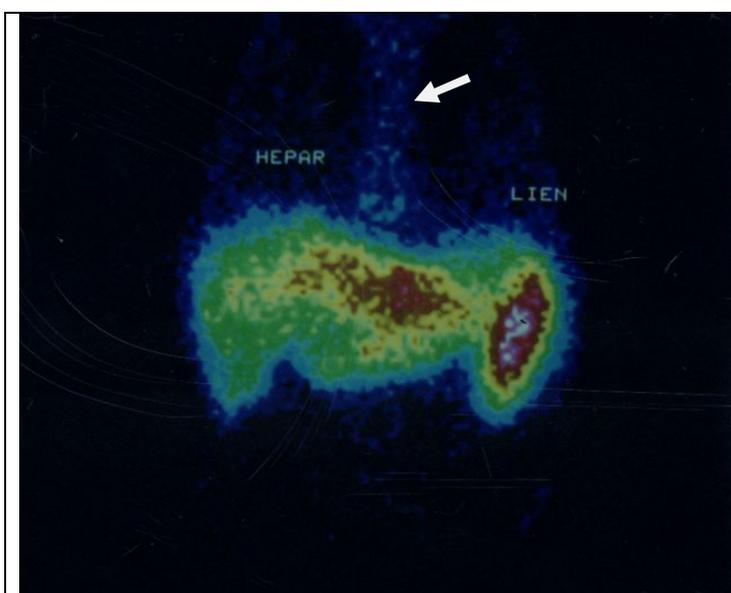


Fig. 8.35. Static scintigraphy
Heterogenous distribution and decreased accumulation of radiocolloid. Anhepatic seizure of radiocolloid shows high accumulation in the lien area (up to 40-50 %) and bone marrow (arrow).
Cirrhosis of liver

At static scintigraphy changes are alike chronic hepatitis. As bloodflow decreases, the image contrast decreases as well, there appears heterogeneity of radiocolloid distribution. Anhepatic seizure of radiocolloid reveals high accumulation in the lien region (up to 40-50 %) and bone marrow (fig. 8.35). CT and MRI reveal the loci of regeneration and liver cirrhosis, dilation of portal and splenic veins, effusion in the abdominal cavity. The X-ray examination of esophagus detecting esophageal varicose phlebectasia is indicated.

Liver cancer is diagnosed when there are changes of echogenicity of hepatic parenchyma, its shape and sizes. Tumoral clusters can be solitary or multiple. At CT decrease of hepatoma density is registered, at MRI – alteration of MR-signal intensity.

As a rule, regardless of growth form dilation of intrahepatic bile ducts is observed. These data can be received at ultrasound, CT and MRI.

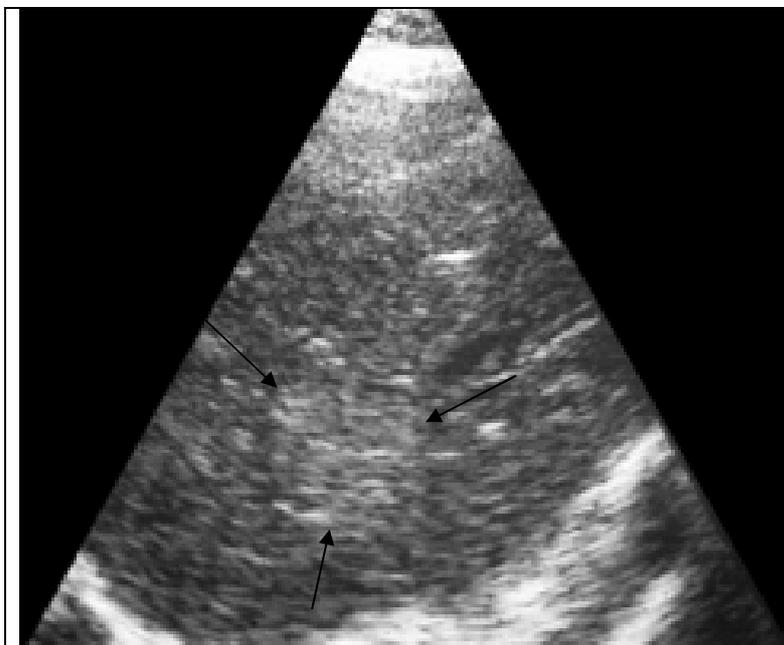


Fig. 8.36. Ultrasound examination of the liver, revealing a hyperechoic lesion (diameter 3.5 cm) with irregular configuration and unsharp borders.

Metastatic liver lesions at ultrasound can be of different echogenicity, either diffuse or focal. Homoechogenic metastasises are revealed by indirect indications (deformation of vascular pattern, local protrusions of contour). They can reach the sizes of more than 1-2 cm. Total sensitivity of contemporary ultrasound at detection of focal hepatic alterations is 60-75 %. At native CT the loci less than 1 cm, some larger loci, cannot be visualized. Standard CT infrequently supplements ultrasound on sensitivity and specificity. CT at metastasis reveals spherical or irregular-shaped areas of low density against the background of parenchyma.

Diffuse liver lesions are more difficult to diagnose with help of CT, unlike the local ones. Sometimes radionuclide diagnostics is preferable at such changes.

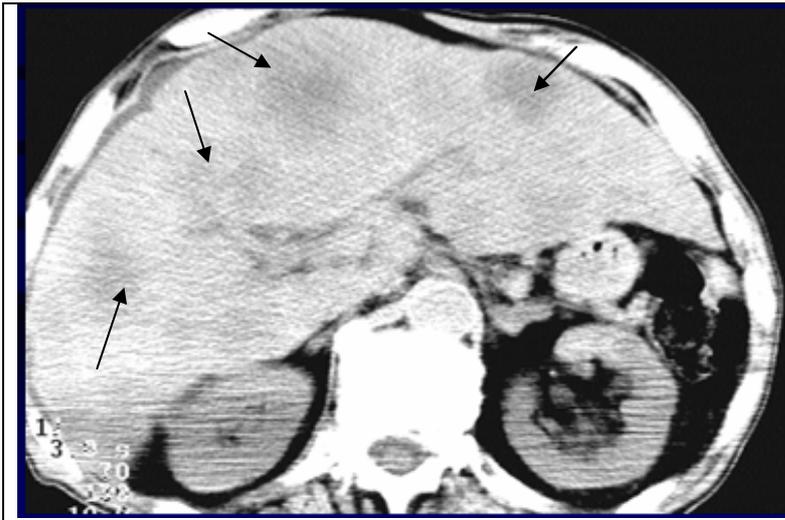


Fig. 8.37. CT at metastasises reveals spherical or irregular-shaped areas of low density against the background of parenchyma.

Capabilities of modern MRI at diagnostics of metastasis in liver can be compared with CT.

Liver cysts. At ultrasound cysts are detected as spherical non-echoes formations. They have distinct, sleek contours and high intensifying echoes behind them. CT and MRI visualize cysts as fluid formations with distinct contours.

Liver abscess. At ultrasound the abscess is detected as hypoechoic or non-echoic zone with rough contours, behind the abscess is acoustic intensification is observed. The liver around the abscess can be hypoechoic. CT shows lesser density decrease at abscess if compared with cysts.

Radiological indications of diseases of gallbladder and bile ducts

Tactics of visualization at gallbladder and bile duct diseases

Acute cholecystitis. US indications of acute cholecystitis (fig. 8.38):

1. Uneven thickening of gallbladder wall (more than 3 mm) with its inhomogeneity, lamination and sometimes indistinct border with liver due to edema and infiltration of perivesical tissue;
2. Exact correspondence of the pain caused by transducer pressure to the location of gallbladder (Murphy's sign).

CT is indicated at complications, when ultrasound is insufficiently informative. It detects gas bubbles in lumen and in the wall of gallbladder at cholecystitis, perivesical modifications better than radiography or ultrasound.

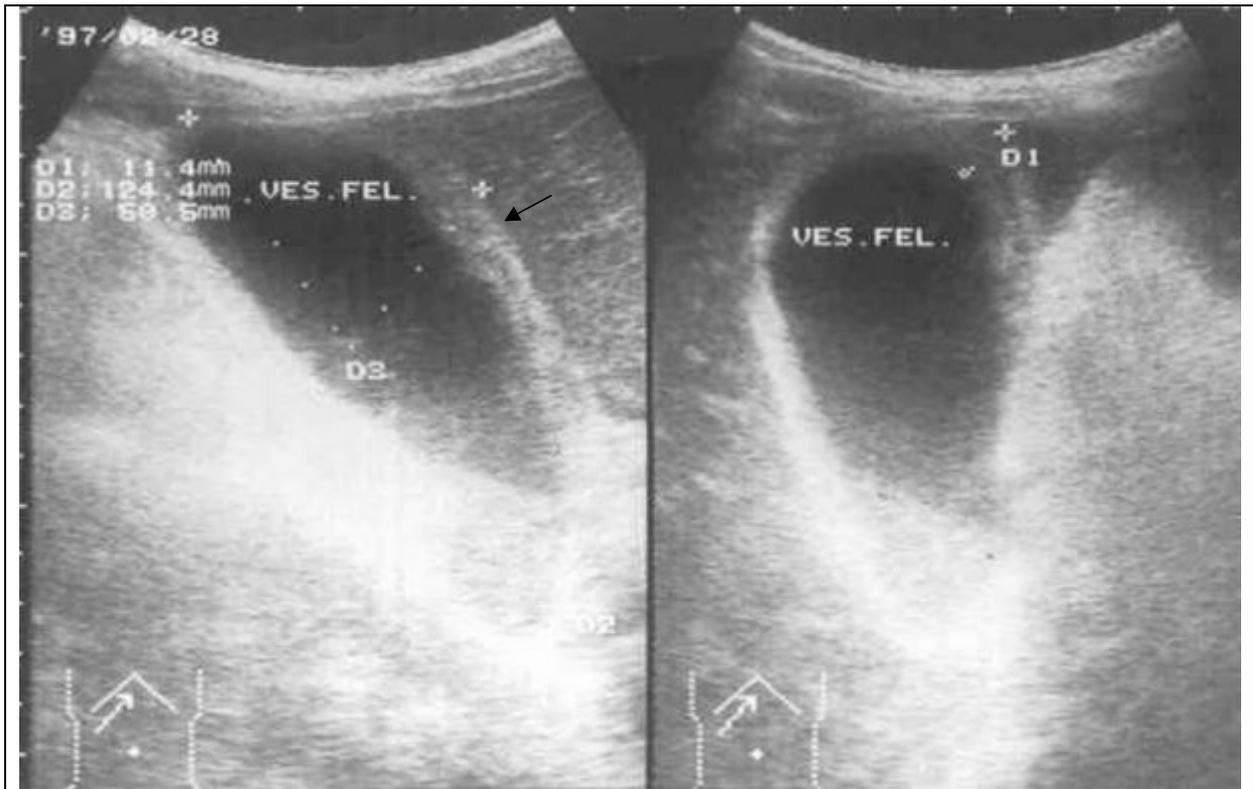


Fig. 8.38. Ultrasound indications: uneven thickening of wall of gallbladder (more than 3 mm) with its inhomogeneity (arrow). Edema and infiltration of tissue around gallbladder. CT is indicated at complications, or when ultrasound is insufficiently informative.

Chronic cholecystitis. Ultrasound indications of chronic cholecystitis:

- Thickening of walls is not typical and can be interpreted as chronic cholecystitis only in view of anamnestic indications.
- Contraction of bladder, rough cicatrical alterations.
- Disorders in gallbladder emptying.

Cholelithiasis. Chronic acalculous cholecystitis is a rare form, calculous cholecystitis is more common.

Ultrasound is primary imaging method. One of its advantages is a possibility to change position of the patient that enables identification of stones. Sensitivity of ultrasound comprises 95-99 %. Stones on sonogram look like hyperechoic formation with acoustic shadow behind it (acoustic track) (fig. 8.39).

The causes of false-negative ultrasound results are:

- small stones in gallbladder neck;
- stone is located deep behind a rib arc.

Cholecystography may help in such cases.



Fig. 8.39. Ultrasound of gallbladder. Stones on sonogram look like hyperechoic formation with acoustic shadow behind it (acoustic track) Calculous cholecystitis.

Gallbladder cancer. Ultrasound is the primary method. If cancer is suspected, CT is indicated. Pattern of early cancer forms is not typical. Tumoural thickening of gallbladder wall is difficult to differentiate from cholecystitis. Tumors substituting gallbladder and extending into hilum and into its tissues (50 % of gallbladder tumors) are usually detected better. Other malignant tumors of this region can be alike.

Cholangiocarcinoma. Common radiological sign of cholangiocarcinoma is dilation of bile ducts above tumoural lesion, gallbladder increases, mechanical jaundice develops, which is revealed by ultrasound, CT, MRI.

Visualization plays the leading role in diagnosing *mechanical jaundice*. Its tasks: to determine presence of obstruction, level of expansion and cause. Ultrasound is primary method. It determines dilation of bile ducts as distinctive feature of mechanical jaundice. During acute period dilation of ducts has no time to develop (when bilirubin indicators suggest mechanical jaundice, repetitive ultrasound, cholescintigraphy, cholangiography is performed).

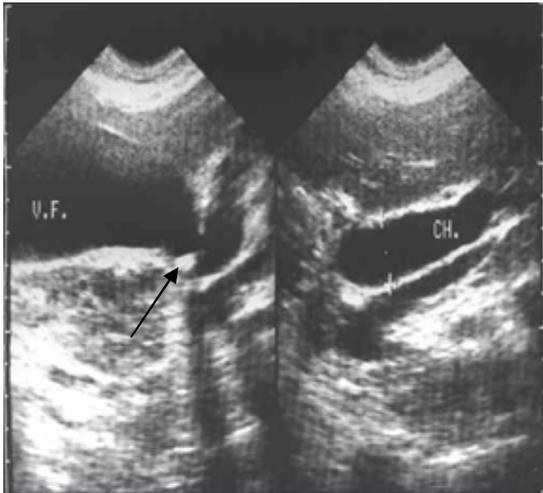


Fig. 8.40. Increased gallbladder with choledochus.
 The basic attribute obstructive icteruses is expansion of bile ducts.
 In the field of a neck of a gallstone (arrow), giving an acoustic shadow.

CT with intensifying enables to identify better than ultrasound, dilation of intrahepatic ducts, and the intrapancreatic part of choledochus is better visualized. CT is better than ultrasound in visualizing distant obstruction of choledochus. CT limitation: gallstones identical in densities with bile are not visualized. CT-cholangiography is a method providing imaging (on the basis of spiral CT) of all contrasted enhanced a biliary tree as opposed to separated into layers at common CT. It is similar with percutaneous transhepatic cholangiography (PTC), endoscope pancreatic cholangiography (EPC) in visualizing the majority of stones in bile ducts and, as a rule, acknowledging or excluding biliary obstruction.

The greatest attention attracts MR cholangiopancreatography which provides with excellent imaging of all biliary tree. In 80-90 % of cases - a pancreatic duct and its leading branches without injection contrast agents. MR cholangiopancreatography is second to direct cholangiography in visualization of ducts and assessment of malignant strictures. But its advantage is in its possibility to visualize both sides of place of obstruction (fig. 8.41).

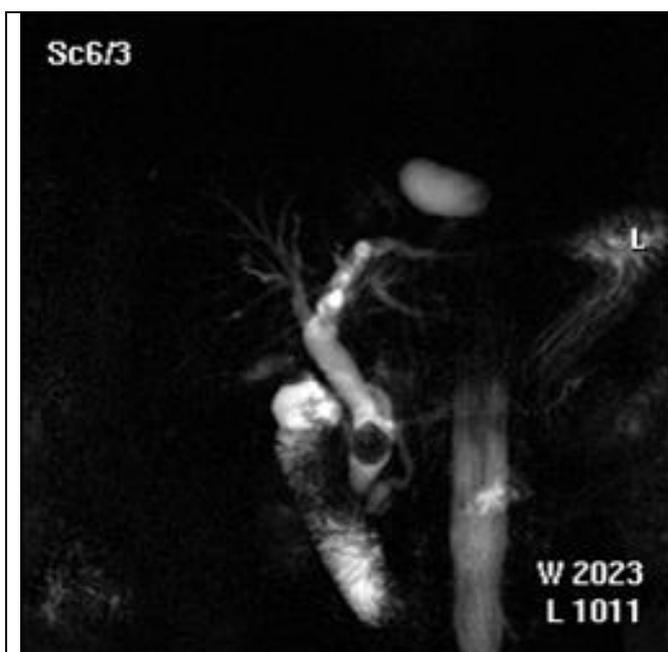


Fig. 8.41. MR – cholangiography. Capabilities MRI are similar with those of CT, but at MRI image can be obtained in all shots, it is possible to obtain the image of hepatic vessels (MR - angiography), bile ducts and pancreatic ducts (MR - cholangiography).

Alternating, or incomplete obstruction of ducts (cholelithiasis), will better be recognized at direct cholangiography and at dynamic scintigraphy with ^{99m}Tc -labeled imidodiacetic acid. .

The best methods of detection of bile ducts narrowings are direct cholangiography: endoscope pancreatic-cholangiography (EPC) and percutaneous transhepatic cholangiography (PTC).

Indications to direct cholangiography:

- non-informative data of ultrasound and CT; however it does not visualize changes outside the duct lumens unlike these methods;
- differential diagnostics of obstructions with steep duct rupture and non-visualizing at ultrasound and CT tumours or stones.

8.3. Radiological examinations of pancreas

Examinations of pancreas usually start with ultrasound; however CT has its advantages. The angiography is applied when CT detected negative or doubtful results. The radiography and fluoroscopy are seldom carried out, as there are more informative methods of visualization. MRI has restricted application, its role is specified.

Pancreas ultrasound. Examination is carried out in the morning (as in mornings not much gas is swallowed, therefore less gas in intestine prevent from performing ultrasound). The tissue of pancreas has homogeneous echostructure. Echogenicity is the same as in liver or a little bit higher. A duct of pancreas in norm is no more than 1,5-3 mm in width. Average thickness of pancreas at adults (the front-back

dimension): head of 2.5-3.5 cm; body – 1.75-2.5 cm; tail 1.5-3.0 see. At children depth: in 3 years of the head of-8 mm; body - 5 mm; tail - 5 mm; in 13 years: head of 2 cm; body – 1.5 cm; tail – 1.5 cm (fig. 8.42).

Spatial resolution of ultrasound at focal lesions of pancreas is 1 cm.

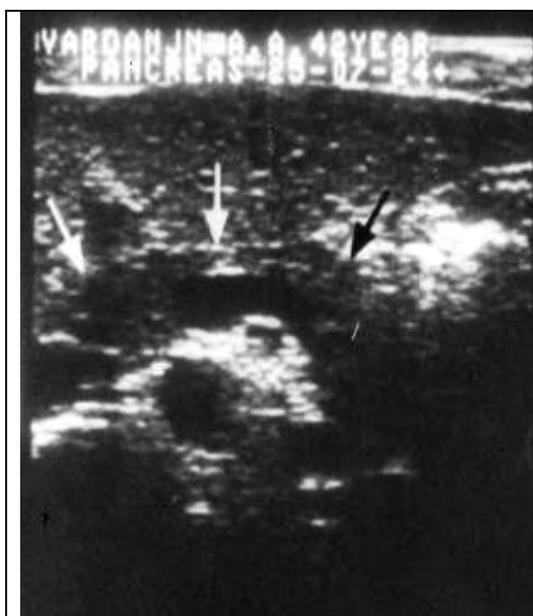


Fig. 8.42. Normal pancreas ultrasound.
Arrows from the left to the right: head, body, tail.

CT. Advantage of CT over ultrasound lies in its better resolving power (3-4 mm). Besides if compared with ultrasound, CT can visualize pancreas at meteorism. CT also visualizes better structures surrounding pancreas (fig. 8.43).

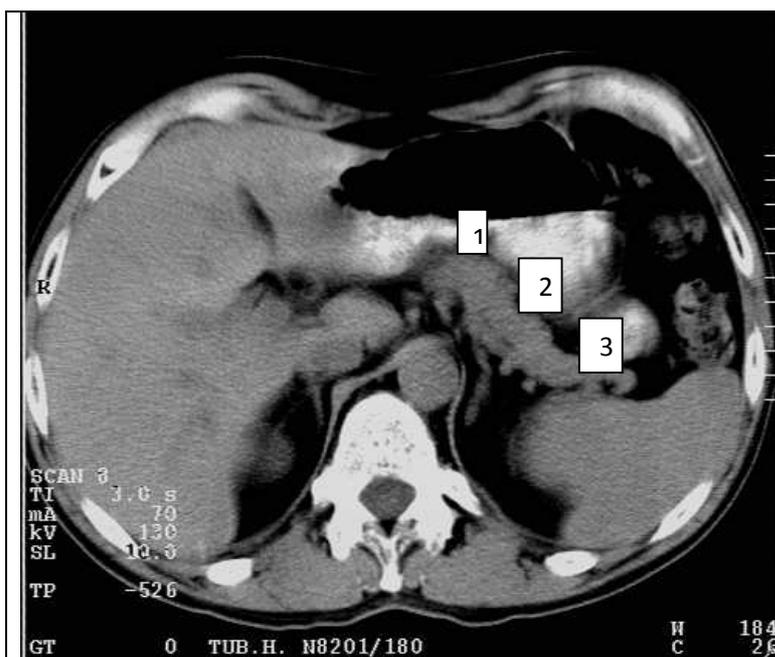


Fig. 8.43. CT-scan pancreas in norm
1-head of pancreas
2- body of pancreas
3-tail of pancreas
Average size of a pancreas at adults
(the front-back dimension) - the head of 2,5-3,5 cm; body- 1,75-2,5 cm; a tail 1,5-3,0 see.

Endoscopic pancreatic cholangiography (EPC). The procedure enables to estimate the status of pancreatic duct and its branches. Indications: making decision on the possibility of surgery at pancreatic cancer, connections of pancreatic ducts with cystic formations.

Radiological signs of pancreatic diseases.

Acute pancreatitis. In mild cases ultrasound image of the pancreas can look normal. In heavier cases edema of organ and related to it enlargement and echogenicity decrease are detected. Wirsung duct can be enlarged. Fluid is identified at abscess, necrosis, marked exudation (fig. 8.44).



Fig. 8.44. Sonogram of pancreas can be diffusely or focally enlarged and relatively hypoechoic if compared to the liver, owing to interstitial oedema, although in early stages or in mild forms no changes may be detected. Associated echographic findings in acute pancreatitis include dilatation of the pancreatic duct and small amounts of fluid surround the pancreas.
Acute pancreatitis

CT is indicated for the patients with non-informative ultrasound because of abdominal distention, which frequently accompanies acute pancreatitis (up to 1/4 patients), the patient with clinical presentation, suspicious of the necrotic or complicated pancreatitis.

Advantages of CT over ultrasound:

- necrotic form can be differentiated more precisely from hydropic one: areas of necrosis do not increase unlike edematous tissue of pancreas;
- is better than ultrasound in assessing peripancreatic dissemination of inflammatory exudate and differentiating fluid aggregations from the phlegmonous infiltrate, consisting from edematous and necrotic tissues of pancreas and retroperitoneal space;
- massive hemorrhage at erosions of vascular walls is recognized more precisely.

CT with intravenous contrasting can confirm abscess suspected by clinical

presentation or ultrasound data, by demonstrating its surrounding ring of contrast intensifying. But puncture with aspiration under ultrasound or CT control can detect infection and abscess formation more precisely.

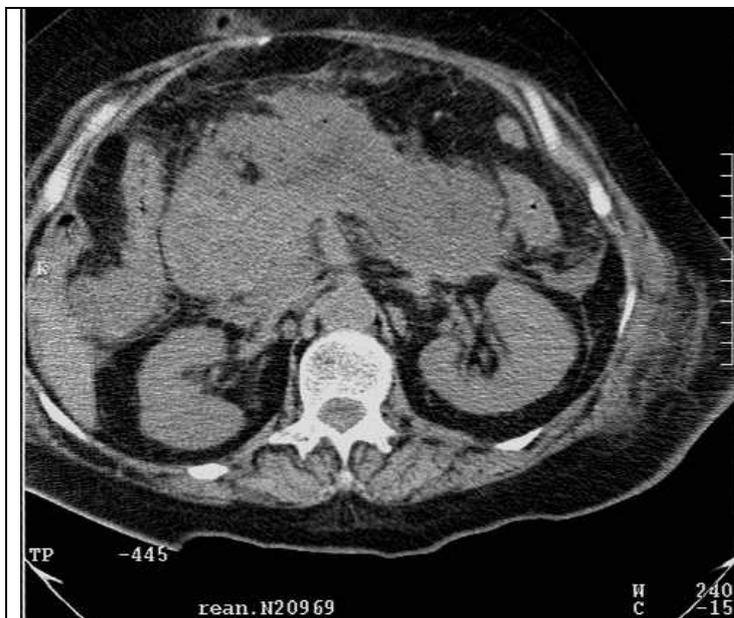


Fig. 8.45. The pancreatic shadow enlarged with unsharp borders.
Acute pancreatitis

MRI also it is accurate in identifying of pancreatonecrosis and can be alternative to CT with contrasting.

Chronic pancreatitis (fig. 8.46.) The calcification of pancreas is frequently detected at radiography. Ultrasonic at early stages of disease can reveal unchanged or not-enlarged, hypoechoic with duct dilation pancreas. At the fibrous form of chronic pancreatitis is gets smaller, there are reinforced and nonhomogeneous echoes of pancreatic tissues. The pancreatic duct may have areas of dilations and narrowings because of stenoses. Concrements and calcifications are revealed. They produce focuses of hyperechogenicity with distal acoustic reduction. CT specifies pathomorphology of affection, especially one of the most important signs - calcifications in pancreas.

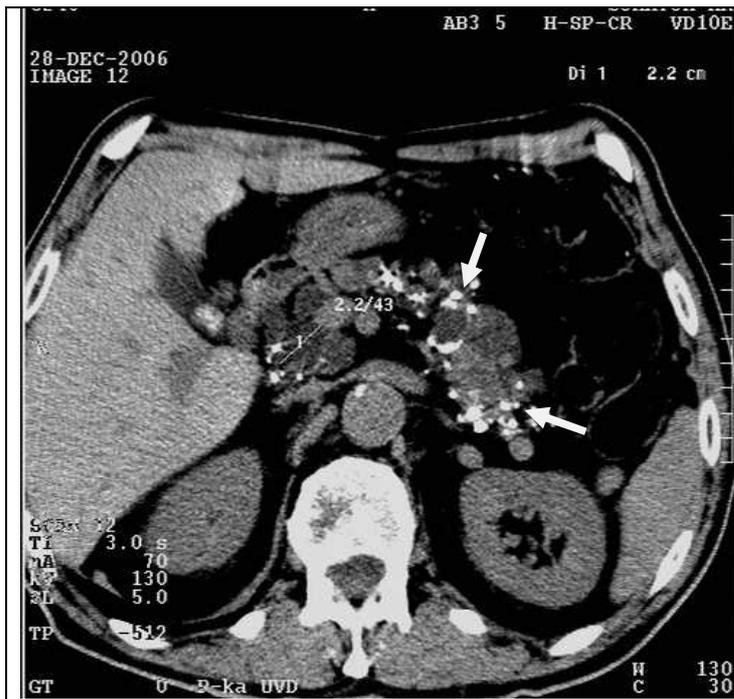


Fig. 8.46. CT improves morphology lesions, especially one of the most important signs - calcifications in pancreas (arrows). Chronic pancreatitis

Pancreatic cancer. Ultrasound enables to recognize the majority of tumours of the head and surrounding departments of pancreas body and their influence on pancreatic and common bile ducts; it is less informative at cancer of tail part and caudal department of body and it is not enough for setting surgical treatment. The most common pancreatic cancer indication is enlargement of its departments. In 70 % of cases the tumour is localized in the area of pancreatic head. Usually cancer is revealed by heterogenous echostructure. Wirsung duct gets bigger. The common bile duct dilates as well at cancer in the area of the head of pancreas.

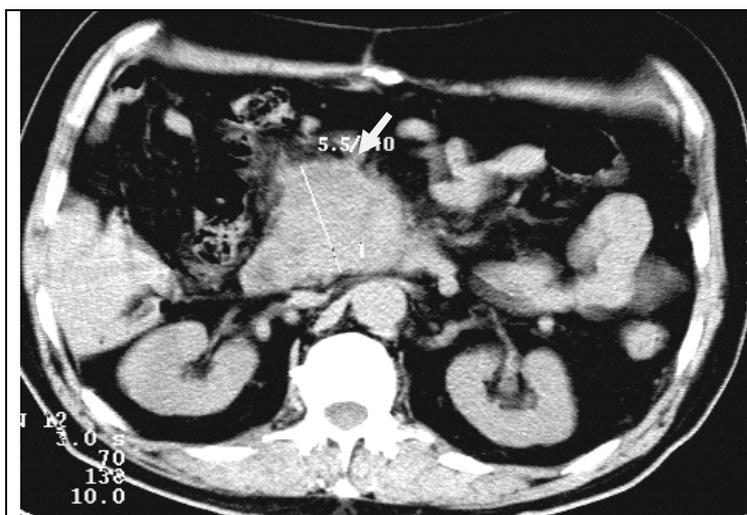


Fig. 8.47. CT-scan. Carcinoma of the head of the pancreas. Large irregular mass originating in the pancreatic head with lower and heterogenic attenuation.

Capabilities of CT in diagnosing pancreatic cancer:

- native CT is not enough sensitive to small tumors;
- method of a choice is CT with intravenous contrasting, providing more precise cancer detection and more reliable estimation of its local diffusion if compared to ultrasound;
- diagnostics of cancer in earlier stage (pancreaticoduodenal resection is possible) are improved by CT with contrasting, at which false-negative results compound only 1-3 %. The images received at the moment of maximal contrast between intensified parenchyma and low-vascularized tumour, enable to detect tumour sized up to 1-2 cm and specify their borders; pancreatic duct can be visualized better.

MRI can serve as an alternative to CT.

CHAPTER 9. URINARY TRACT IMAGING

9.1. Radiological researches of urinary tract

Radiological researches are indicated for each patient in whom kidneys, ureters, urinary bladder diseases are suspected.

Assignments are carried out by the attending physician, formulating the primary goal of research. In contact to a radiologist the order and volume of radiological researches is established.

Ultrasonic scanning of kidneys.

Due to harmlessness and high informativeness ultrasound in most cases is the first method with which research in urological clinic begins..

For kidneys ultrasound a patient does not need special preparation, however if products causing bloating are avoided, ultrasonic diagnostics becomes more exact.

Detection of kidneys at ultrasonic scanning is about 100 %. However in patients with adiposity of the III-IV stage (much adeps absorbing a significant part of ultrasonic energy), hypoplasia, dislocation of a kidney they are hardly detected).

Ultrasonography is carried out both on the back and on the abdominal cavity.

In examination on the abdominal cavity the right kidney is detected through the liver. The left kidney in such body position is hardly detected because of the intestine. Kidneys examination are performed through the right and left side in the supine and standing position in different scans.

Ultrasononic scan in longitudinal direction shows that the normal kidney has the oval form and precise contours. The size of it on the average at the adult makes 7,5-12,5 cm, width of 4,5-6,5 cm, thickness 3,5-5 cm. Distinction in length of kidneys does not exceed 1,5-2 cm. The kidney in newborns proportionally is larger in volume and mass, than in adults. Proportions of kidney thickness, width and lengths in a newborn is 1:1,5:2; in an adult - 1:1,5:3. In anewborn the length of a kidney is 4-4,5 cm, width - 2,5-2,7 cm and thickness - 2-2,3 cm. The kidney is covered by connective tissue with a capsule appearing as a continuous light stripy 1-1,5 mm in width. Renal cortex and the medullary substance causes dark area (almost free from echoes – hypoechoec) with width of ≈ 15 mm (up to 25 mm). This peripheral zone represents parenchyma (fig. 9.1). Normal renal cortex has lower echogenicity, than the spleen or the liver. The central zone is defined as a congestion of echostructure with non-homogenous reflection, corresponding to renal pelvis, major and minor renal calices. Normally the front-back size of renal pelvis does not exceed 1,0 cm. In norm the ureters is almost not detected, except for the top third.

Due to low selfdescriptiveness ultrasonic scanning of ureters and vessels of kidneys except for rare cases has no great practical value.

Opportunities of ultrasonic scanning as method of initial visualization:

- allows to estimate position of kidneys, dislocation at breath, sizes,



Fig. 9.1. Ultrasononic scan in longitudinal direction. Peripheral zone represents parenchyma (hypoechoec, arrow). The central zone is detected as a congestion echoes with non-uniform reflection (arrow with a rhombus). Norm.

form, outlines, a differentiation of parenchyma on the renal cortex and renal medulla; renal sinus with renal pelvis and calix and perirenal tissues;

- focuses concerning character of a disease, necessity of the further visualization and a choice of its method;

- the majority of stones in kidney and urinary tract is visualized;
- the method is high-sensitive to obstruction of urinary tract;
- allows to reveal diffuse and focal changes in the parenchyma of kidneys.

Disadvantages of the method:

- does not give the information on function of kidneys;
- ureter is badly visualized.

Ultrasound of the urinary bladder.

This method is safe and informative enough. It is possible only if the urinary bladder is well filled with urine or disinfectant solution. The sizes depend on a degree of its filling (average capacity 250-300 ml). The filled bladder normally is free from echoes, has precise contours, is located in the small pelvis cavity behind symphysis pubica. More often it has an oval or pear-shaped form. In norm thickness of the bladder wall in case of its filling is 3-6 mm, and the mucous membrane is less than 2 mm.

The prostate is located directly behind the bladder and in norm has smooth contours. The tissue of the prostate is represented by alternation of hypoechoic sites and fine dot and linear structures (fig. 9.2). Length of the prostate is 2,5-4 cm, front-back size comprises 1,8-2,5 cm, and transverse size is 2,7-4,2 cm.

In transurethral or rectal exam it is possible to receive images of the top, average part and the basis of the prostate.

Now ultrasonic scanning has taken the central place in research of urinogenital system since it has the big diagnostic value, is simple, cheap and harmless.

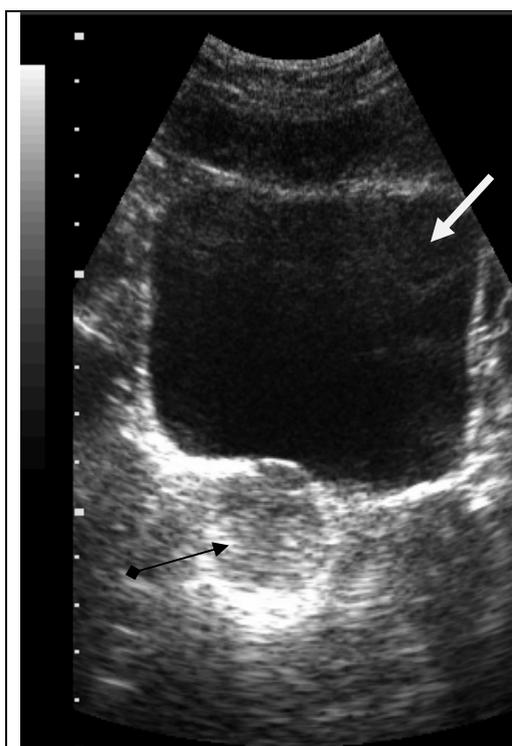


Fig. 9.2. Ultrasonic of the urinary bladder
Urinary bladder (arrow). Prostate (arrow with a rhombus).
Norm. Transverse scan.

Usual ultrasonic gives the information on morphology, but not on function. Ultrasound is an excellent auxiliary method at various intervention procedures, such as nephrostomy, biopsy and drainage.

X-ray researches

First of all it includes a survey film. Preparation: to clear intestine in the evening and in the morning of the day of research. X-ray study should be performed on an empty stomach. Exception includes the patients with sharp renal colic. Survey examination should be performed on the 30×40 cm film. It should cover area of all the urinary tract, starting from X thoracal vertebra and finishing the symphysis pubica.

Interpretation of survey film includes a rating of quality of an image, definition of correctness of a projection, studying of a shadow picture of soft tissues, a bone skeleton, organs of GT, kidneys, the ureters, the bladder.

Kidneys are located as bean shaped shadows at the level of XII chest - II lumbar vertebrae from the left and I lumbar - III from the right. Upper poles are located closer to a median line, than a lower one. Contours of kidneys shadows normally are smooth and look like arched lines, convex in the lateral side (fig. 9.3).

Size of kidneys at radiological research in adults: length is 11,5-13,7 cm, width is 5,1 - 6,7 cm. Normal ureters in a survey film are not visible. The empty bladder in a usual film is not detected. Survey radiography of kidneys and the bladder in a direct projection helps to reveal stones and gas. It is a general part of all usual radiological researches of the urinary tract which should precede researches with use of contrast agents.

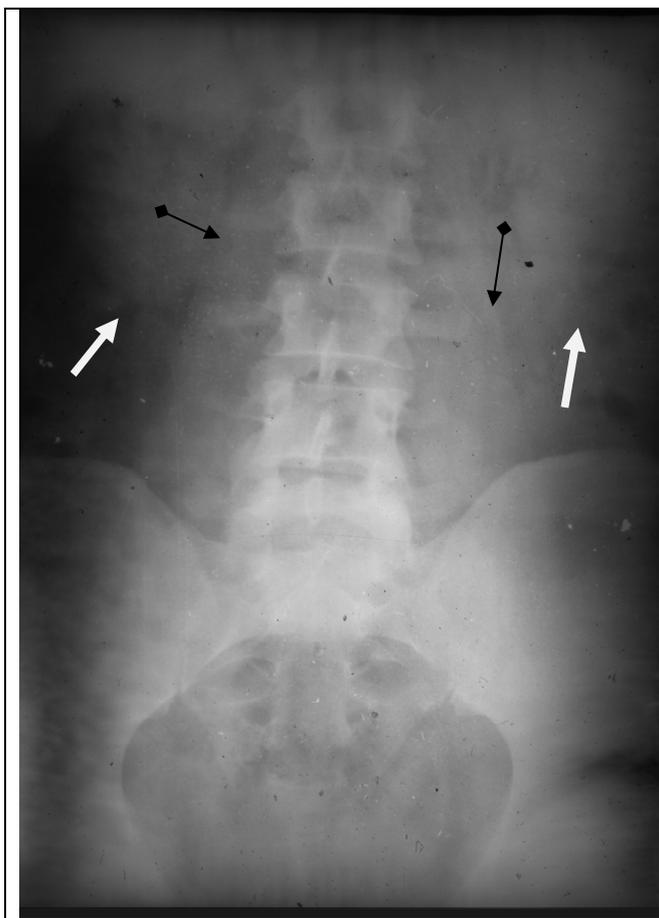


Fig. 9.3. Normal abdomen.
Kidneys (arrows). Psoas (arrows with a rhombus).
Norm.

Intravenous urography (IU). IU is important mode of kidneys research. Opportunities of its application concern to advantages of IU in children's practice, at narrowings of the urethra, at traumas of kidneys and renal bleedings.

In IU contrast substance is injected intravenously (on 1 kg of weight - 1 ml of the solution containing 300 mg of iodine per/ml).

Contraindications to research: the increased sensitivity to preparations of iodine and a poor patient's condition.

Films are made during the first 60 second, that allows to see kidneys during nephrography phase, but more often in 5-7 min. and 20-25 min. In nephrography phase there is a distinct shadow of the whole renal parenchyma, containing contrast substance, which arrives in renal calyx and pelvis. In a healthy person the shadow of renal parenchyma is homogeneous. Later an image of pelvis appears. Displacement of the renal pelvis lower than the III lumbar vertebra is the abnormal phenomenon. Kidneys are mobile during breathing; their excursion in a vertical direction can achieve 10 cm. In research in horizontal and vertical position of the patient displacement of a kidney in identical conditions of a respiratory pause should not be higher than 1,5 vertebrae. Renal pelvis usually settles down within the limits of a kidney, but can settle extrarenally. The shortest distance from a pelvis contour up to a lateral contour of a kidney shadow normally is 2-3 cm. The form of renal pelvis is various, but the basis is more often triangular, longitudinal to the body axis.

Upper and external borders of the pelvis are convex, bottom one is concave (fig. 9.4). Sizes of the pelvis are variable; its capacity in average is 6-7 cm³. There are major and minor renal calices. Usually there are 3 major renal calices, they connect pelvis to major and minor renal calices. In each major renal calyx there is the basis - its junction with pelvis, the neck - a middle part of the major renal calix as the lengthened tubule and the apex from which one or several small calices depart. The number of minor renal calices is from 4 to 20. In each minor renal calix three parts are distinguished: neck - the narrowest part in the place where the minor calyx detaches from the major renal calyx, actually the calyx and the arch which surrounds cone shaped papilla. As minor renal calices settle down in different planes it is not always possible to receive the image of each of them, therefore in many cases it is necessary use multiprojective research.



Fig. 9.4. Intravenous urography.
Norm.

During reading of IU it is possible to observe various phases of emptying of the upper urinary tracts, since calices and pelvis and finishing terminal departments of ureter.

As emptying of calices occurs nonsimultaneously normal IU shows that one calix is filled with contrast substance while others do not contain it, as they are in a phase of contraction. Similar phases of a systole and diastole appear on a series of films.

Normal ureter is represented as shank-shaped shadows which correspond to filling by contrast substance of separate segments in a phase of a systole and diastole.

In the majority of people 3 segments is common, less often – 2. Ureters with contrast substance are visible as a band with width from 3 to 10 mm. IU allows to make radiological research of the bladder as well (descending cystogram).

Advantages of IU:

- 1) Prompt examination of all urinary tracts;
- 2) An opportunity to detect structure of renal pelvis and calices;
- 3) Detection of stones, especially in the ureter;
- 4) Exact diagnostics of obstruction.

Disadvantages of the method:

- 1) Dependence on kidneys functional ability;

2) Unsatisfactory opportunity to estimate structure of renal parenchyma on presence of cysts or solid formations;

3) All kidney contours are hardly detected; frequently it is impossible to detect formations starting from forward or back kidney parts;

4) Impossibility to estimate perirenal space;

5) Necessity to use contrast agents and radiation;

6) Impossibility to investigate a level of glomerular filtration. However the latter can be estimated if blood of the patient will be taken 3-4 hours after the introduction of contrast substance and investigated on the contents of iodine.

Ability of urography to show detailed anatomy of renal pelvis and calices is important for diagnostics of papilla necrosis, tumours of renal pelvis and urinogenital tuberculosis. The method is exact in diagnostics of stones in urinary tract, but concedes CT on sensitivity.

Its role in obstruction of the urinary tract is being discussed; the combination of a survey film, ultrasonic scanning and scintigraphy represents alternative, but in presence of acute obstruction IU is the important diagnostic method. Congenital developmental anomalies, for example, adnation of kidneys, rotation, variants of renal pelvis and calices structure, are very well visible with the help of IU. In traumas when the minimal damage of kidneys is supposed, the urography enables prompt and effective inspection.

Retrograde ureteropyelography. The retrograde ureteropyelography is a direct injection of contrast agent (75-100 mg of iodine / of ml, 7-8 ml) in a lumen of the upper urinary tract (fig. 9.5). The preparation can be injected through a catheter, fixed in the ureter in cystoscopy. Retrograde ureteropyelography is used when there is intolerance to a contrast agent injected in blood in a patient. Most commonly these are stones or less usually polyps or small urethelial tumours arising from the ureteric wall, or rarely a blood clot.



Fig. 9.5. Retrograde ureteropyelography
Norm.

The method is demonstrative for diagnostics of:

- 1) Minor changes of the mucous;
- 2) Diverticula and cavities;
- 3) Various processes including obstruction, when intravenous urography is not informative;
- 4) Absence of the image of the upper urinary tract in intravenous urography (in obvious cases, for example, in a big tumour, it is more preferable than CT);
- 5) In patients with risk of intravenous injection of iodine content contrast agent, limiting application of IU;

The method is contraindicated in acute inflammatory processes in kidneys and urinary tracts and in macrohematuria.

Retrograde ureteropyelography almost is completely superseded by application CT and MRI.

Angiography: in this method a catheter is fixed in venous or arterial systems. The end of a catheter is placed under the fluoroscopy control in a vessel entering the examined area or emerging from it (fig. 9.6). Renal angiography is used seldom nowadays for detection and differential diagnostics of volumetric formations because of wide use of ultrasonic and, especially, CT. Angiography can be used in case of elective operation on the abnormal kidney or in case of a kidney resection.



Fig. 9.6. The selective arteriogram of the left kidney.
Norm.

Other indications for renal angiography include suspicion on renal arterie stenosis and aneurysm (fig. 9.7). Angiography is necessary before vascular operations, such as embolisation, stenting or balloon dilation of the renal arterie.

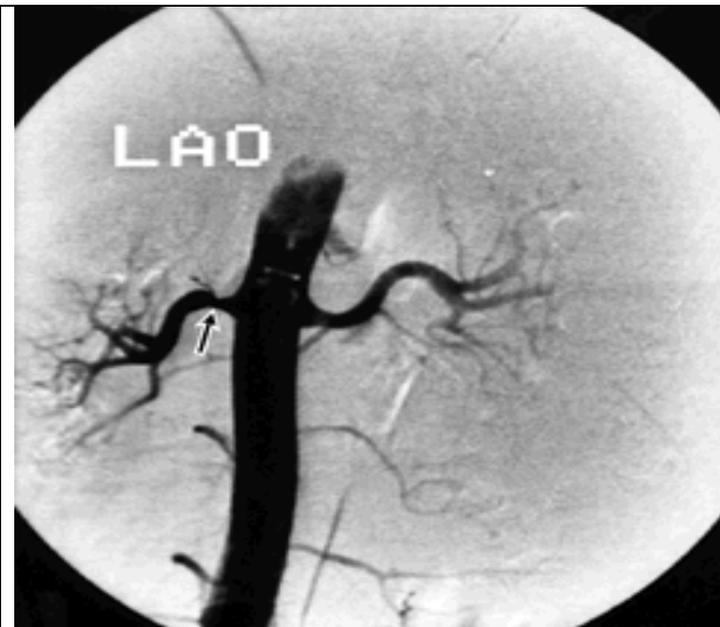


Fig. 9.7. Angiography:
The stenosis of the renal arterie (arrow).

On a series of films in the beginning the image of the aorta with its large branches, including renal arteries (an early arterial phase), then a shadow of small arteries (a late arterial phase), further the common increase of kidneys shadow intensity (nephrography a phase), a weak shadow of renal veins and, at last, the image of pelvis and calices is received since the contrast substance is discharged from blood with urine. Renal arteries depart from the aorta almost at a right angle at the level of the Ist lumbar vertebra or a disk between it and the IInd lumbar vertebra. Diameter of the renal arteries trunk makes 1/3-1/4 diameters of the aorta at this level. Length of the right artery is 5-7 cm, and left one is 3-6 cm. Contours are smooth, a shadow is homogeneous and intensive. Diameter of renal veins is 1-1,5 cm, diameter of the vena cava inferior at the level of the kidneys portal is not larger than 2,5 cm.

Cystography. Films for IU are usually made for research of the bladder 0,5 - 1 hour after introduction in of contrast agent blood (fig. 9.8).



Fig. 9.8. Intravenous urography. Norm.

Considerably more precise image is achieved by means of ascending cystography, carried out with liquid or gaseous contrast substances (fig. 9.9).



Fig. 9.9. Ascending cystography.
Norm.

The normal bladder has oval, spherical or the pyramidal form. Its lower border is located at the level of symphysis pubica; upper border achieves the level of the IIIrd sacrum vertebra. In women in case of insignificant filling of the bladder by a contrast substance the normal bladder gets the saddle form dependent on uterus pressure. Contours equal are smooth.

More often cystography is performed for diagnosing of posttraumatic or postoperative extra bleeding, diverticulum, bladder-ureter reflux and tumors detection (fig. 9.10, 9.11).



Fig. 9.10. Cystography.
Bladder-ureter a reflux.

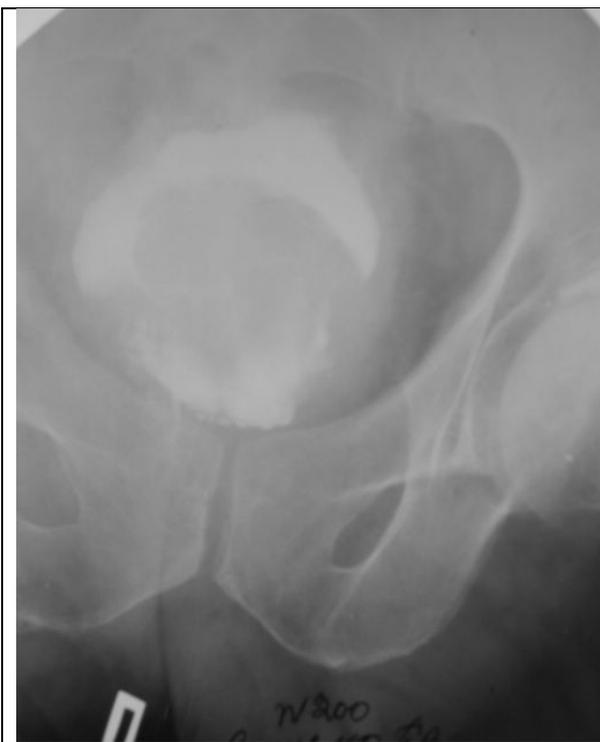


Fig. 9.11. Cystography.
Extensive defect of filling connected with a wall of the bladder with rough contours is defined.
Cancer of the bladder.

Urethrography. It can be ascending (at urination) or retrograde. The image during urination gives the information on the posterior urethra, while the anterior urethra is not well visible (fig. 9.12). Retrograde urethrography gives more information on the anterior urethra, than on the posterior one.



Fig. 9.12. Ascending urethrography.
Norm.

Computerized tomography (fig. 9.13). CT is an excellent method for revealing and diagnosing of volumetric formations of kidneys, and also for definition of a stage of malignant tumours in kidneys. The method is very informative in stones diagnosing. CT surpasses ultrasonic in revealing perirenal, periureter and pelvic the processes touching urinary tract.

CT is a method of choice for evaluation of consequences of kidneys trauma when severe organ damage is suspected. CT is the best method of visualization of adrenal glands and the method of choice in these diseases diagnosing. A new method of renal pelvis and calices visualization is computerized tomographic urography (in presence of a spiral tomograph), carried out with intravenous contrast enhancement. Three-dimensional reconstruction on a spiral computer tomograph shows the image of kidneys vessels.



Fig. 9.13. CT, axial section, after contrast medium injection, middle contrast medium phase.

MRI.

Visualization of pelvic organs (the bladder, prostate, uterus and genitals) is one of important fields in MRI. The method gives the valuable information on a stage of a tumoral process; it detects volumetric formations more precisely, than CT. Now MRI of kidneys is carried out when the diagnosis is not clear after CT and ultrasonic scanning, when there is intolerance of contrast preparations, and in vascular lesions (fig. 9.14). MR-urography (MRU) is completely non-invasive method; it does not demand introduction of a contrast agent, does not depend on function of kidneys and it can be applied in patients with renal insufficiency.

MRU enables to receive the image of urinary tract comparable on quality and results with IU and even from a retrograde ureteropyelography. Expansion of urinary tracts is visualized, the level and, in most cases, the reason of obstruction are distinguished. MRU with paramagnetic contrast enhancement displays both anatomy of urinary tract, and function of kidneys, it is comparable with dynamic nephroscintigraphy. Advantages of MRU allow consider it a method of future.

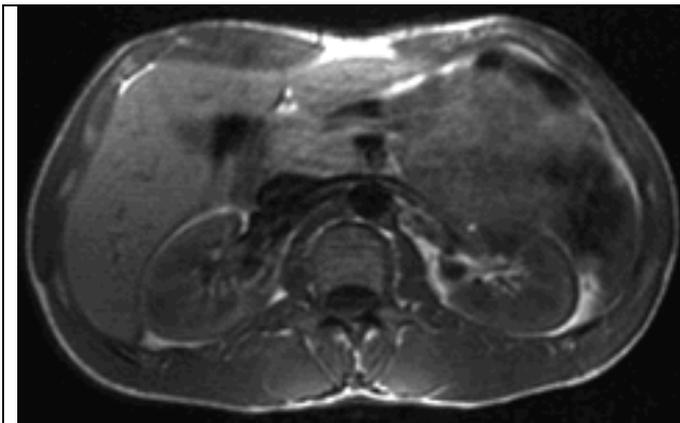


Fig. 9.14. MRI of the abdominal cavity at the level L2. Axial T1-WI normal kidneys.

Radionuclide renal imaging.

A radionuclide study of the kidneys in the clinic has received general distribution and recognition. They enable to study a functional status of: 1) renal tubular cells; 2) glomerular filtration; 3) excretory phase; 4) a status of a vascular channel and parenchyma of kidneys, kidneys topography.

Following kinds of radionuclide kidneys researches are distinguished:

- 1) Radiorenography (studying of renal tubular cells function and excretory phase with ^{131}I -orthoiodohippuric acid);
- 2) Dynamic nephroscintigraphy (research of glomerular filtration with $^{99\text{m}}\text{Tc}$ -DTPA (the pharmacological moiety is a pentavalent chelating agent);
- 3) Angyonephroscintigraphy (research of the renal blood flow with $^{99\text{m}}\text{Tc}$ -DMSA. The pharmacological moiety $^{99\text{m}}\text{Tc}$ -DMSA is dimercaptosuccinic acid).

Radiorenography. The technique consists in graphic registration of changes of a radio-activity above each kidney and above heart area after intravenous introduction of ^{131}I -orthoiodohippuric acid. On character of elimination ^{131}I -orthoiodohippuric acid is mainly renal tubular cells (80 % secretion by renal tubular cells, 20 % is filtered by glomerulars). Radioiodine can be injected in the thyroid gland; therefore the blockade of the thyroid gland with potassium iodine is necessary.

Two curves reflect work of kidneys, and one above the heart – clearance (fig.9.15).

The first segment of a curve is a quality indicator of a kidney blood supply. Time of initial ^{131}I -orthoiodohippuric acid (a vascular segment) passage lasts in average 17-20 sec.

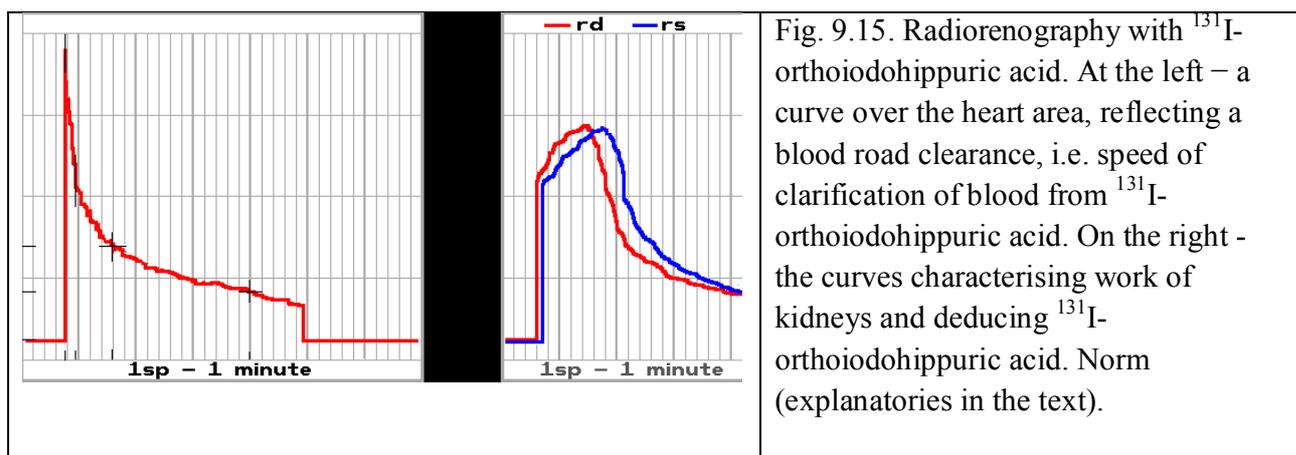
The second segment rises slower - 2,5-4 min., it is a secretory phase. This phase is regarded as a reflection of, at least, three factors: accumulation of ^{131}I -orthoiodohippuric acid by renal tubular cells, removing of a preparation in a glomerular tubulars and clarifications of blood from a preparation. The point of the hinge rise of

a curve reflects the period of time balance between process of accumulation and excretion of ^{131}I -orthoiodohippuric acid in a kidney, it is the end of the IInd segment.

The third segment reflects removing of a preparation from a kidney. $T_{1/2}$ 8-10 min. (up to 15 min.). In norm the difference in height of right and left kidneys curves amplitude does not exceed 10 %, as well as time parameters.

The third curve of radiorenography (above area of heart) is a curve of clearance of ^{131}I -orthoiodohippuric acid; it shows speed of blood clarification from radiopharmaceutical. The first 3-4 min. from the beginning of research it reflects the common delution of ^{131}I -orthoiodohippuric acid, and in a later period it is a parameter of total activity of kidneys.

Effective renal flow of plasma is detected: radio-activity in blood on the 20th min; 40th min is measured and compared to the entered activity on the special formula. Normally, renal flow of plasma equals to 500-800 ml /min./1,73 of m^2 . Selective decrease of the effective renal flow of plasma is observed in arterial hypertension, in heart and sharp vascular insufficiency.



Dynamic nephroscintigraphy (research of glomerular filtration with $^{99\text{m}}\text{Tc}$ -DTPA (the pharmacological moiety is a pentavalent chelating agent).

The glomerular filtration agent used is $^{99\text{m}}\text{Tc}$ DTPA, of which 10–15 % is extracted on the first pass.

The image of distribution of given radiopharmaceutical in parenchyma of kidneys and graphic registration of a preparation transfer in kidneys is received (fig. 9.16).

With the help of a special formula (computer) the volume of functioning parenchyma (area) in % is calculated. Norm is 100-90 %. The glomerular filtration is

calculated according to a special formula as well. There are special tables depending on age. On the average $T_{1/2}$ of glomerular filtration equals to 100-140 ml / minutes. Blood half-life in norm is 18 minutes on the average.

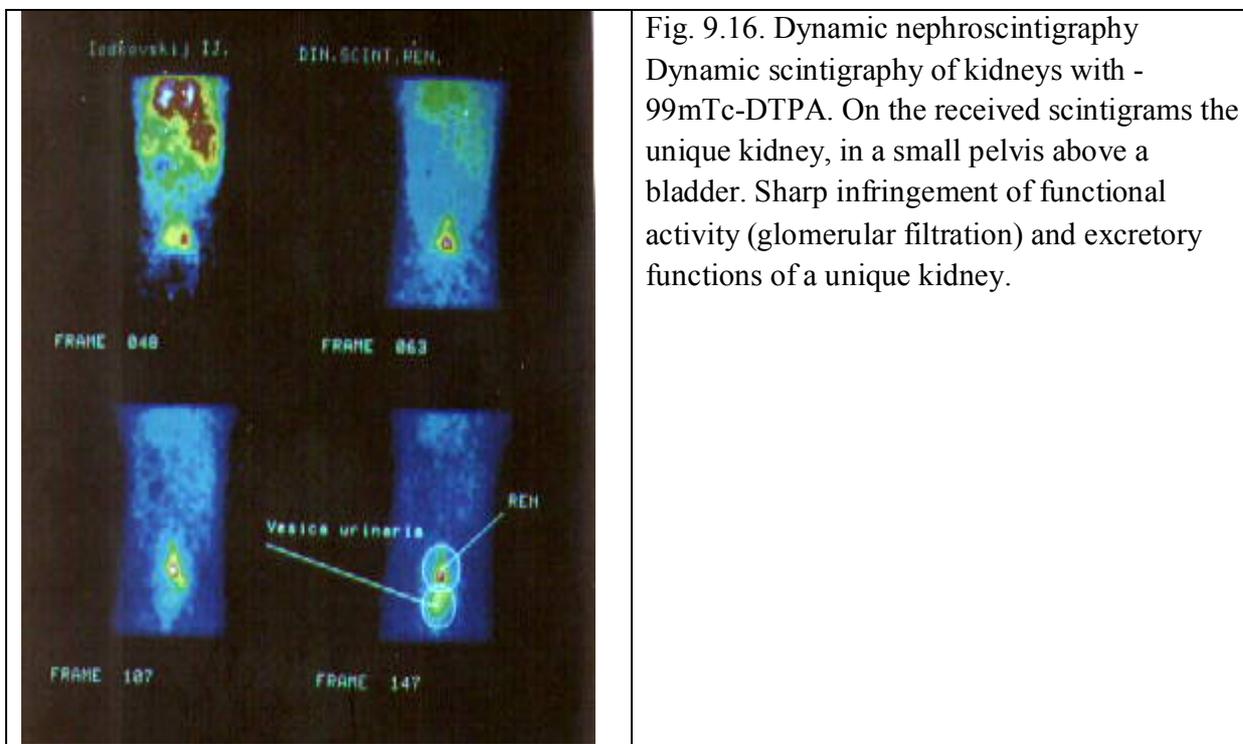


Fig. 9.16. Dynamic nephroscintigraphy
Dynamic scintigraphy of kidneys with -
 ^{99m}Tc -DTPA. On the received scintigrams the
unique kidney, in a small pelvis above a
bladder. Sharp infringement of functional
activity (glomerular filtration) and excretory
functions of a unique kidney.

Angyonephroscintigraphy. The renal tubular cell uptake marker in clinical use is ^{99m}Tc - DMSA. A dose of 2.5–3.0 MBq/kg (max. 80 MBq) is injected into the patient, the radionuclide is extracted by the renal tubular cells but not excreted into the tubuli, thus marking regions of poor renal parenchymal function (fig. 9.17, 9.18, 9.19). This is a static imaging method and in a sense functions as a chemical microsphere (perfusion agent). It is mostly used for the detection and follow-up of pyelonephritis. The pharmacological moiety ^{99m}Tc - DMSA is dimercaptosuccinic acid. The received information with ^{99m}Tc - DMSA allows estimating a renal blood flow as a whole in each kidney and its separate parts. It has the great diagnostic value in revealing infringements of renal blood supplies in each kidney separately, that allows to estimate presence of renal arteries stenosis.

The following parameter is used: transit time is the time from occurrence of the maximal intensity count rate above the aorta till the maximal count rate on a kidney. In norm the transit time is 8-9 sec.

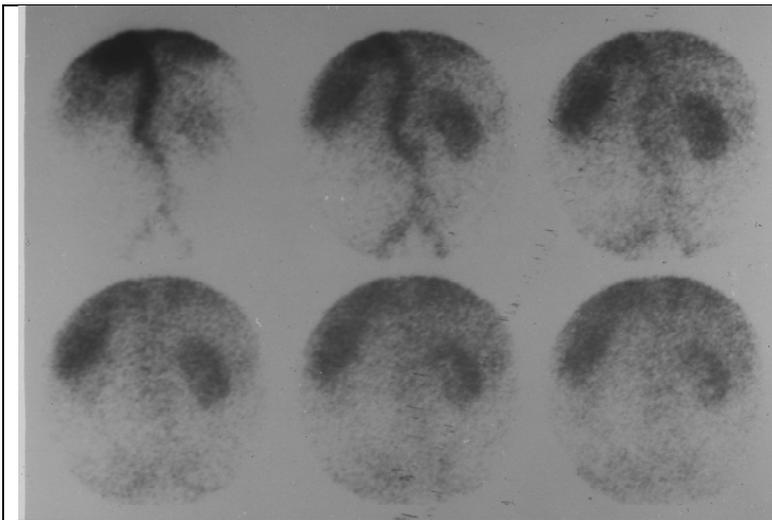


Fig. 9.17. Angyonephrosintigraphy with ^{99m}Tc - DMSA. Accumulation ^{99m}Tc - DMSA in the aorta and blood vessels of kidneys.

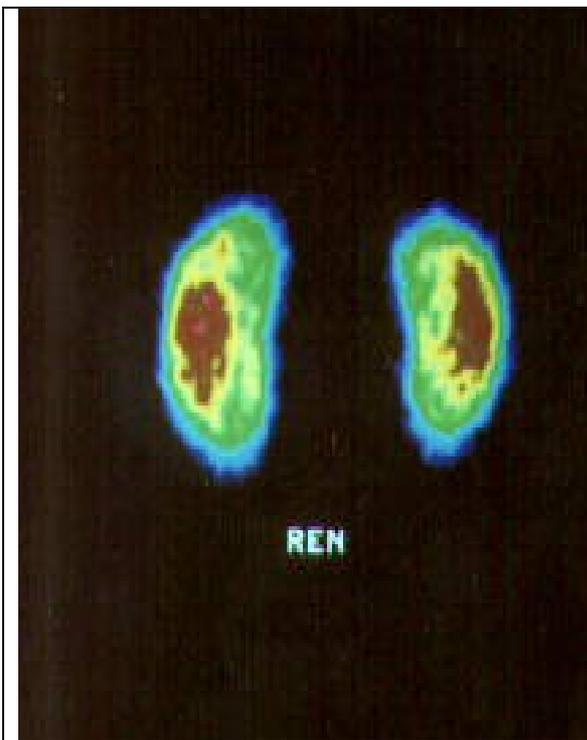


Fig. 9.18. Angyonephrosintigraphy Static scintigraphy of kidneys with ^{99m}Tc - DMSA. Accumulation ^{99m}Tc - DMSA by both kidneys intensive enough and uniform. Both kidneys of the usual form, the sizes and a position. Norm.



Fig. 9.19. Static scintigraphy of kidneys with ^{99m}Tc - DMSA (dimercaptosuccinic acid)
 On a scintigram only the left kidney is defined. Accumulation of RFP by a left kidney is intensive enough; its distribution is diffusively non-homogenous, in the top pole is detected a defect of radionuclide accumulation. Focal lesion of the top pole of a left kidney. The right kidney is not detected.

So, radionuclide renal imaging, nuclear imaging methods can help to evaluate bilateral renal function individually. There are three types of renal examinations available in nuclear medicine. There are radiopharmaceuticals to evaluate glomerular filtration, renal excretion and renal tubular cell uptake markers. In combination with pharmacological "stressors" such as furosemide (furosemide renography and captopril (captopril renography), these methods are used for a wide range of purposes to evaluate renal function in renal disease such as the follow-up of renal function in patients with renal congenital malformations and pyelonephritis. In the adult, the tests can be used to identify renal vascular hypertension, to assess renal function prior to nephrectomy and renal transplants.

If the initial study is normal or near normal, the patient is then administered the angiotensin converting inhibitor orally and the isotope study is repeated 1 hour later following reinjection of the radionuclides. If stenosis of renal artery occurs there is virtually no function in the kidney with stenosis of renal artery. The healthy kidney has normal curve.

9.2. Radiological symptoms of illnesses and damages of kidneys

Radiological diagnostics of congenital kidneys anomalies.

Kidneys aplasia. On survey films, as well as on IU, the shadow of one kidney is absent, and renal pelvis and ureters are not filled by contrast agent injected intravenously.

The basic ultrasonic sign which should guard concerning unilateral aplasia, is a definition of obviously increased kidney owing to its compensation hypertrophies. From the opposite side the kidney is not found out.

With the help of aortography only one renal artery can be detected. With the help of CT and MRI, executed both with contrast enhancement and without it, only one kidney and one vascular bunch can be detected.

Kidneys hypoplasia. Unilateral and bilateral hypoplasia is distinguished. In hypoplasia kidneys are of considerably smaller size, however their macrostructure remains normal. It is detected by intravenous contrast enhancement, thus there is no deformation of renal pelvis and calices and there is no infringement in urinary excretion. With the help of CT and MRI it is possible to perform precise measurements of kidneys, and in presence of contrast enhancement it is possible to make sure that their contrast enhancement is simultaneous. In ultrasonic scanning kidney with hypoplasia has smaller sizes, but ultrasonic structure is not damaged.

Double kidney. Double kidney is one of the most often developmental anomalies of the upper urinary tract (fig. 9.20). It can be uni- and bilateral. Doubling from the one side is observed more often, than from both sides. In anatomic-topographical understanding double kidney represents a single organ consisting of the upper and lower segments. A double kidney has two pelves, two ureters and a single fibrous capsule. With the help of contrast enhancement two isolated pelves and calices can be detected in one kidney. CT is less informative, taking into account the limited opportunities of ureters imaging. Presence of two isolated pelves and calices in one kidney is detected on CT with the help of amplification and longitudinal reconstruction, and on MRI on frontal scans. Ultrasonic scanning allows to identify two hyperechoic central complexes in the background of the enlarged kidney hypoechoic parenchyma structure.



Fig. 9.20. Retrograde ureteropyelography.
Note the double renal pelvis from the upper pole of the left kidney and duplicated ureter.
Duplication of the upper collecting system.

Nephroptosis. Except the congenital reasons there are following reasons of this disease development: decrease of intra-abdominal pressure, reduction perirenal fat, increase in kidney weight, traumas of structures fixing a kidney. X-ray research identifies it in various positions of a patient (laying on a back, vertically). IU has the greatest value nephroptosis detection. The increase in kidney mobility is detected in a change of body position on more than body of the lumbar vertebra high, sharp pelvis-ureter angle and twisting of the ureter with expansion of pelvis-calices system (fig. 9.21).



Fig. 9. 21. Intravenous urography. A standing position. Left kidney pelvis at the level of IV lumbar vertebrae. Acute an angle between pelvis and ureter.
Nephroptosis of a left kidney.

Radiological diagnostics of kidneys inflammatory diseases

Acute pyelonephritis. The majority of kidneys acute inflammatory diseases are accompanied by their enlargement.

In addition to clinical methods ultrasonic scanning is indicated, it is an important initial technique since it helps to see stones, hydronephrosis, intrarenal or perirenal abscesses. Ultrasonic signs of acute pyelonephritis are: a kidney enlargement (but it can have normal sizes), echoes decrease, expansion of renal pelvis and calices (fig. 9.22).

Some changes of renal parenchyma, connected with inflammatory process, are better detected by CT, than by ultrasound, and consist of spotty areas, characteristic of insufficient blood supply, small dense sites, puffiness of perirenal fat. CT shows formation of microabscesses 0,5-1 cm. The density is close to liquid density (8-12 HU).

Angyonephroscintigraphy with ^{99m}Tc -DMSA also is informative, as it shows the located infectious centers before they become visible by ultrasonic scanning or CT. Research with ^{131}I -orthoiodohippuric acid shows decrease of renal tubules function.

IU during acute inflammatory process in a kidney, as a rule, does not give the qualitative information though in some cases a kidney enlargement, moderate expansion of renal pelvis calices and the ureter, decrease of kidney function is detected.

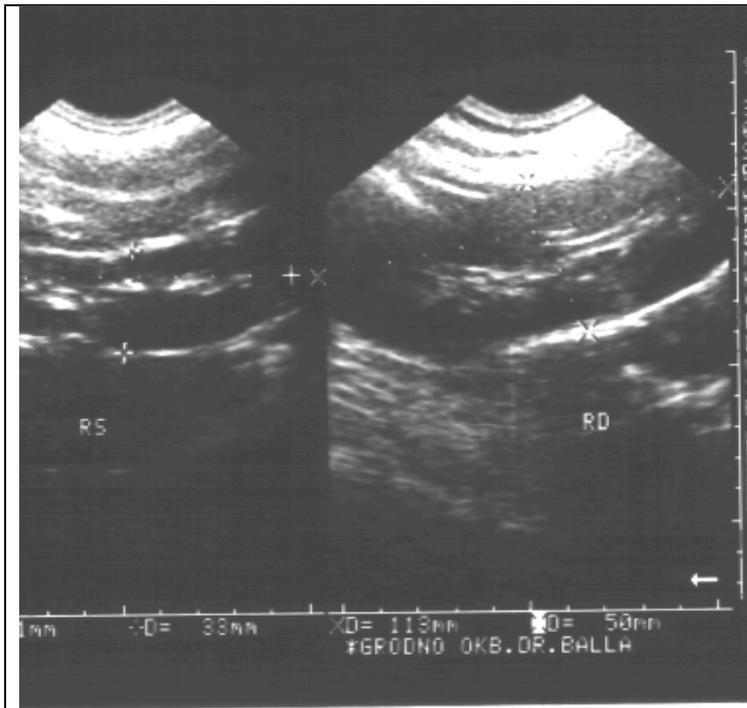


Fig. 9.22. Acute pyelonephritis
Sonogram of kidneys. Enlarged
parenchyma of a right kidney (26 mm)
Acute pyelonephritis.

Severe pyelonephritis in inadequate treatment or tolerance of flora to antibiotics can result in chronic inflammatory process or abscess of a kidney. IU detects hardly defined contour of a lumbar muscle on the side of lesion, diffuse increase in kidney or volumetric formation in its background, deformation of renal pelvis and calices. In ultrasound the abscess is detected as hypoechoic or anechoic volumetric formation with a liquid or dense inclusions in liquid and with increased “through transmission” beneath (fig. 9.23). Abscess walls look like a hyperechoic ring. CT without enhancement shows the hypodensity zone within the limits of an abscess cavity (fig. 9.24). Abscess walls with contrast agent application are enhanced and contents are not present. MRI gives the similar information.

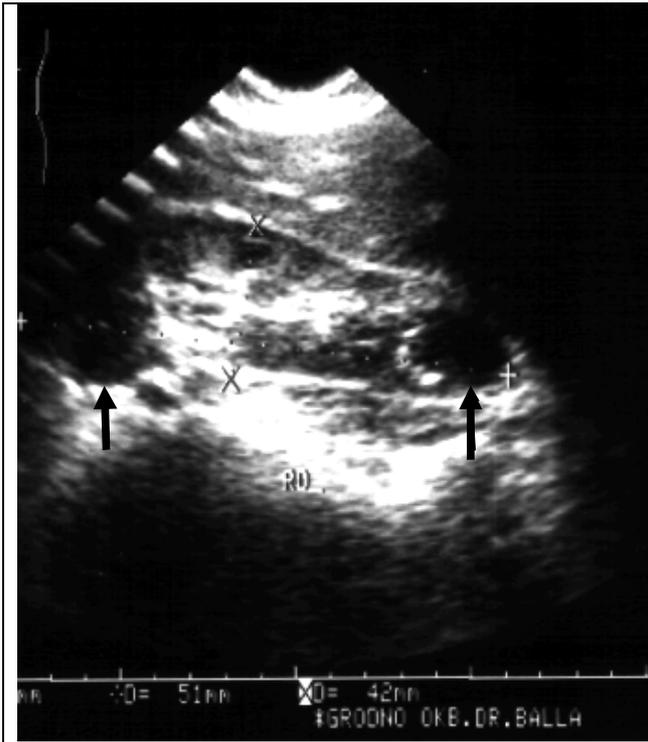


Fig. 9.23. Abscess of kidney
Sonogram along a long axis of right kidney.
Abscess of kidney as hypoechoic zones with indistinct contours (arrows).



Fig. 9.24. Abscess of kidney
Computer tomogram of the abdomen
cavity at the level of L2. Left kidney is
deformed with presence of
pseudocystic formations.
Abscess in left kidney.

The chronic pyelonephritis. Disease seldom arises in patients with unchanged urinary tract. Visualization is applied, mainly, for specification of nephrosclerosis evidence. IU detects reduction of one or both kidneys sizes, deformation of renal pelvis and calices. Intravenous urography doesn't show renal scarring precisely in comparison with scintigraphy.

Ultrasonic scanning marks atrophy of the parenchyma and fibrosis areas (fig. 9.25). CT detects renal scarring and roughness of a kidney contour. Ultrasonic scanning helps to distinguish pyelonephritis from hypoplasia displaying change of a

kidney structure. In hypoplasia MRI shows steady reduction of the renal artery and its branches.

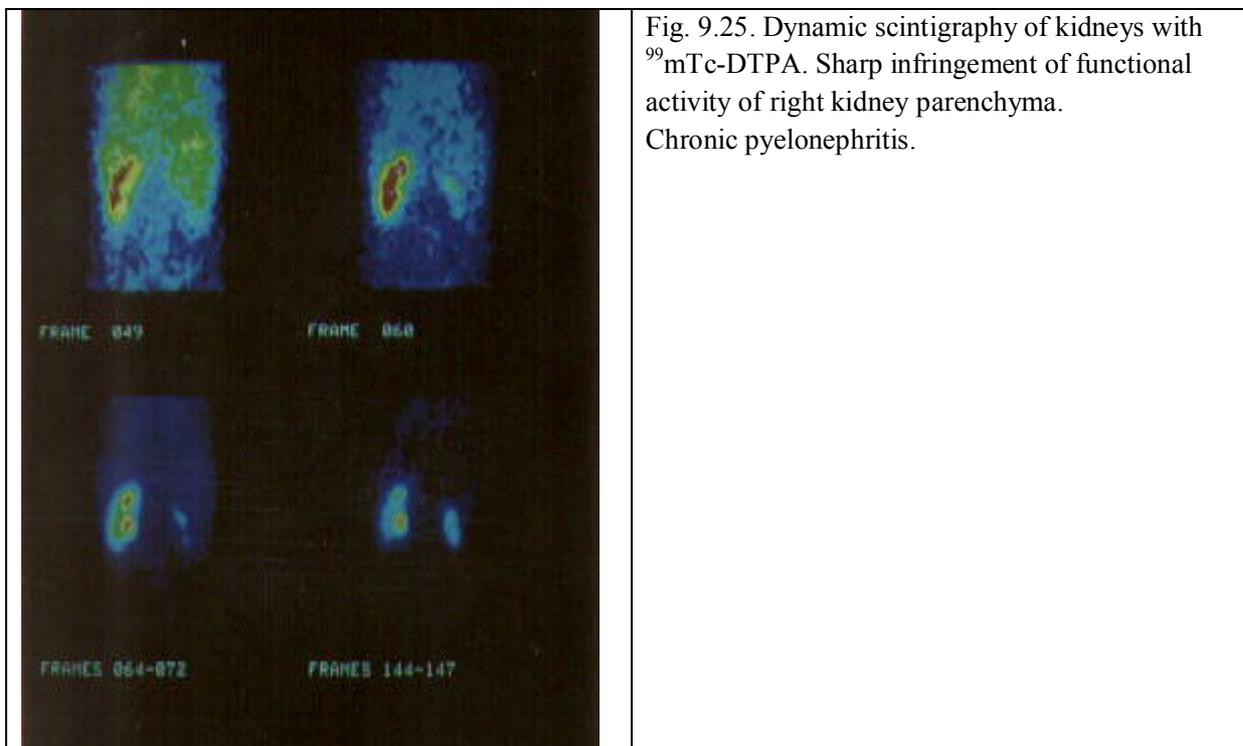


Fig. 9.25. Dynamic scintigraphy of kidneys with ^{99m}Tc -DTPA. Sharp infringement of functional activity of right kidney parenchyma. Chronic pyelonephritis.

Tuberculosis of the kidney. Tuberculosis of the kidney in its early stages may produce nonspecific changes such as papillary necrosis (fig. 9.26). With progression of the disease, the more characteristic findings of stricture of a renal pelvis, caliceal amputation, and cavitation may occur.

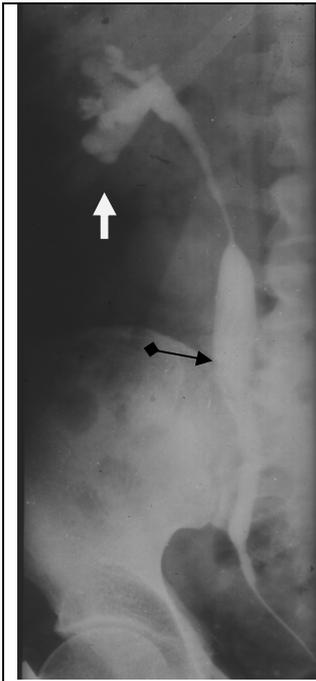


Fig. 9.26. Cavitation in bottom pole of right kidney (arrow), the upper segment of ureter is narrowed, average and bottom are expanded (arrows with a rhombus).
Tuderculosis of right kidney and the ureter.

Tuberculosis also causes ureteral strictures. A combination of renal and ureteral abnormalities such as strictures should suggest the diagnosis. The end stage of renal tuberculosis is a small, shrunken, nonfunctioning kidney that often contains calcific debris (“putty kidney”) (fig. 9.27).

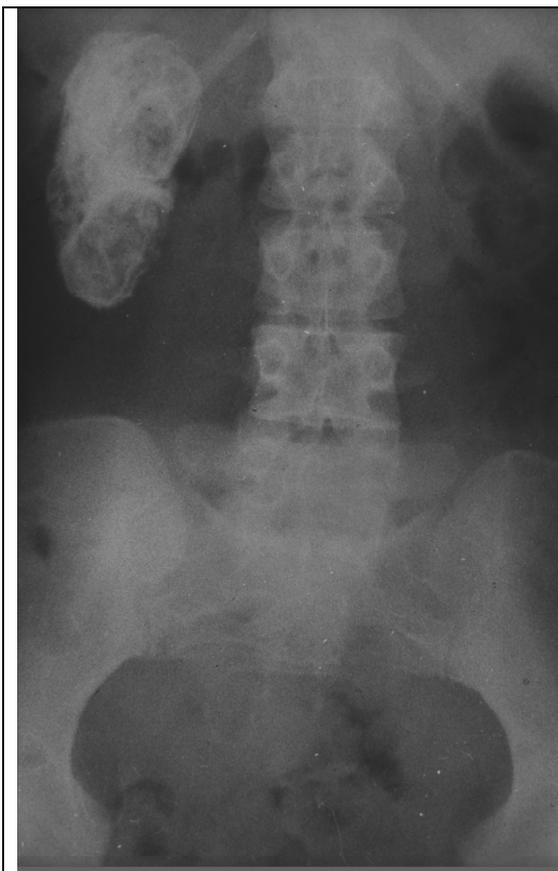


Fig. 9.27. Nonfunctioning right kidney containing calcific debris (“putty kidney”) is present. Renal tuberculosis.

Changes of chronic bladder inflammation include thickening and irregularity of the wall secondary to muscular and mucosal hypertrophy.

Nephrological diseases of a kidney

Acute glomerulonephritis. Kidneys are enlarged, reduced or their sizes do not vary. Biopsy of kidneys in many cases is necessary for exact diagnosis. Each patient with renal insufficiency should undergo ultrasonic scanning.

Examination with contrast substances (urography, CT) should be avoided in patients with the reduced kidneys function as contrast preparations can promote the further decrease of kidneys function.

Early sign of acute glomerulonephritis is decrease of glomerular filtration, detected with the help of ^{99m}Tc -DTPA.

Urinary calculus.

Stone formation may occur due to metabolic abnormality, structural disorders or recurrent urinary tract infection. Because approximately 90% of all urinary tract calculi are radiopaque, the plain film of the abdomen is the keystone of radiological diagnosis (fig. 9.28, 9.29). Calculi can be obscured or easily overlooked when they

overlie bony structures (transverse processes of lumbar vertebral bodies or especially the sacrum).



Fig. 9.28. Survey roentgenogram of the abdomen cavity. The intensive spherical shadow with precise contours is detected in the area of a left kidney. A stone. Urolithiasis.



Fig. 9.29. Survey roentgenogram of the pelvis. In the bladder area the intensive spherical shadow with precise contours is detected. A bladder stone. Urolithiasis.

Numerous extraurinary calcific densities that overlie the urinary tract may be confused with uroliths, the commonly encountered ones being calcified costal

cartilages, gallstones and vascular calcifications. Ureteric calculi can be confused with bone islands in the sacrum and phleboliths.

An intravenous urography can localize a calculus to the kidney or ureter, and evaluate the degree of obstruction the stone is producing. After intravenous contrast administration, stones may be either completely or partially obscured by excreted contrast or appear as a filling defect. The degree of obstructive uropathy often bears no relation to the size of a ureteric calculus. Perhaps the most consistent urographic finding with a ureteric calculus is the presence of a continuous column of opacified ureter expending from the renal pelvis to the site of the calculus. Some degree of ureterectasis is usually also present if ureteric obstruction has been present for more than a few hours.

Ultrasonography can differentiate renal calculi from other causes of pyelocalyceal filling defects such as tumours or blood clots. The sonographic diagnosis of a calculus is based on the demonstration of a highly echogenic focus that produces an acoustic shadow (fig. 9.30). Stones as small as 0.5 cm can be reliably detected in this manner. This technique assumes greatest importance when faced with a nonopaque filling defect on urography. Tumours and clots lack a distal acoustic shadow.

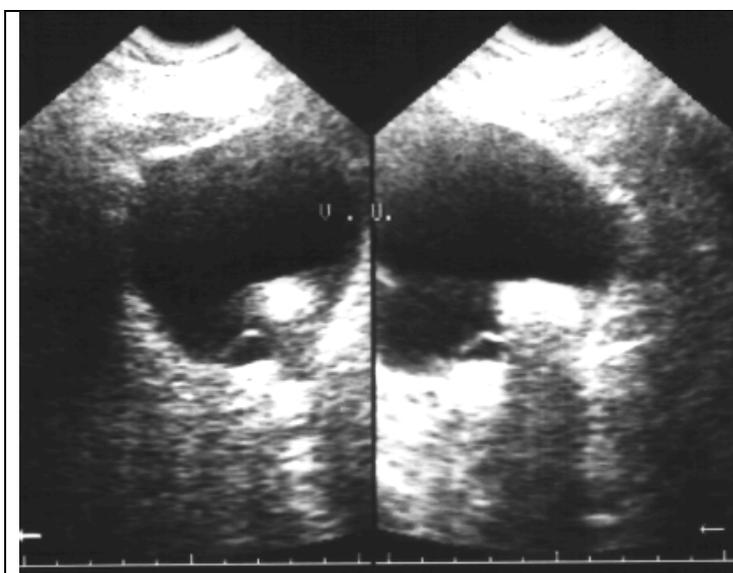


Fig. 9.30. Sonogram of the bladder. A stone in the bladder with hyperechoic frame is defined. Hypoechoic acoustic shadow. Urolithiasis.

Recently, it has become apparent that noncontrast helical CT (HCT) has major advantages over intravenous urography in the evaluation of patients with urolithiasis. Noncontrast HCT studies can be completed much more rapidly than intravenous urography, as there is no need for oral or intravenous contrast administration or other

patient preparation. Virtually all types of urinary tract calculi contain enough calcium to be visibly hyperdense on noncontrast HCT. It has been demonstrated that stones are more accurately detected with noncontrast HCT than standard radiography, nephrotomography, intravenous urography, or sonography. Noncontrast HCT provides no direct functional information. MR imaging has not yet had a major impact in this area because stones lack mobile protons and generate no signal with standard MR imaging techniques.

Renal cell carcinoma

Renal cell carcinoma, (RCC) is the most common renal tumour, comprising approximately 85% of all primary malignant renal neoplasms. Renal tumours are usually solitary, although bilateral tumours are encountered in approximately 2% of patients. Histologically, the most common type of malignant renal cell cancer is clear cell adenocarcinoma. Before widespread use of cross-sectional imaging (ultrasound (US), CT, MRI), renal cell cancer often presented as an advanced disease at the time of diagnosis. Today, however, there has been a shift to a smaller size and lower stage of renal cell cancer at the time of diagnosis. RCC may be locally aggressive, extending into the renal veins and inferior vena cava (IVC) or invading adjacent soft tissue structures. RCC can metastasize by lymphatic and haematogenous routes. Common sites of haematogenous metastases include bone, liver, and lungs. Nodal metastases commonly involve pararenal and para-aortic nodes and may also include mediastinal and pulmonary hilar nodes.

Imaging. Imaging plays an important part in the detection, characterization and staging of renal cell cancer. Although the intravenous urogram (IU) is still often used as the initial study in the search for renal masses, it has been shown that in the presence of a CT-confirmed renal mass, detection by IU is only 21% when the lesion is smaller than 2 cm, 52% when the lesion is 2–3 cm, and 85% when the lesion is 3 cm or more in diameter. A normal IU, therefore, does not exclude the presence of a renal mass.

IU detects following characteristic tumour signs

- 1) Kidney enlargement, increase in distance between cavities of a kidney and its contour, displacement of a kidney, rotation around of a longitudinal axis;
- 2) Deformation of renal pelvis, defect of its filling, serrated pelvis contours;
- 3) Changes on the part of calices: partial or full disappearance; narrowing or expansion, and displacement of calices;
- 4) Change of the ureter position and its narrowing in the upper part due to the big tumour of a kidney bottom pole and metastases in regional lymph nodes.

When compared with CT, US demonstrates detection of 60% of lesions smaller than 2 cm and 83% of lesions between 2 and 3 cm in size. Lesion detection on contrast-enhanced MRI (90–97%) equals that of CT (89 – 99%). US, CT, and MRI have all been used with varying degrees of success in the characterization of renal masses. On US, the appearance of renal cell carcinoma is variable. Approximately 86% of tumours are isoechoic, 4% are hyperechoic, and the remainder are hypoechoic as compared to the adjacent renal parenchyma.

Ultrasonic scanning is an initial method of visualization of RCC. RCC on ultrasonic scanning is defined as a formation of wrong spherical or oval form with rough contours. In most cases kidney cancer has nonhomogenous structure; in parenchyma additional echoes appear, caused by cysts and necrosis sites, calcifications, haemorrhages. Deformation of a kidney and its enlargement is visualized. Deformation, displacement or reduction of renal pelvis and calices is quite often detected.

Ultrasonic as an initial method of visualization of kidneys allows:

- to find out the majority of cancer tumours;
- to distinguish them (beginning with 4-5 cm tumours) from benign tumours with nonhomogeneous structure;
- to detect metastasises in lymph nodes and the liver;
- to exclude the second kidney lesion.

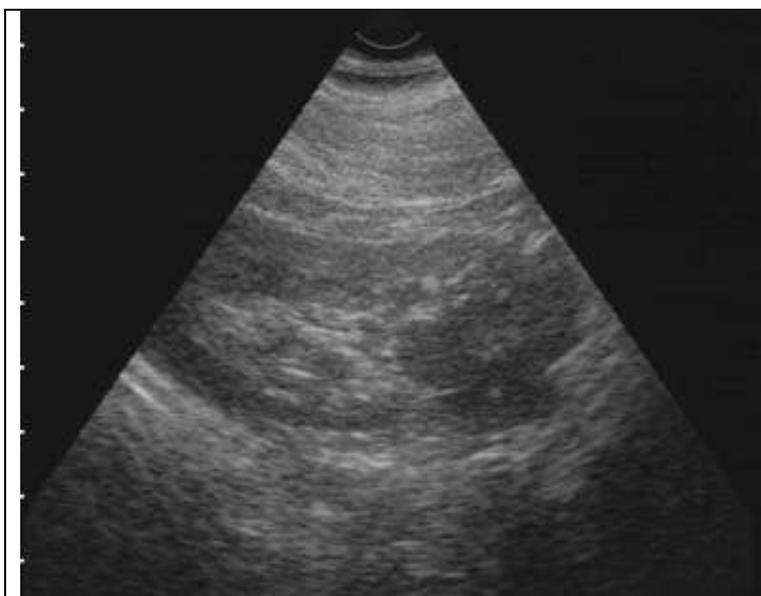
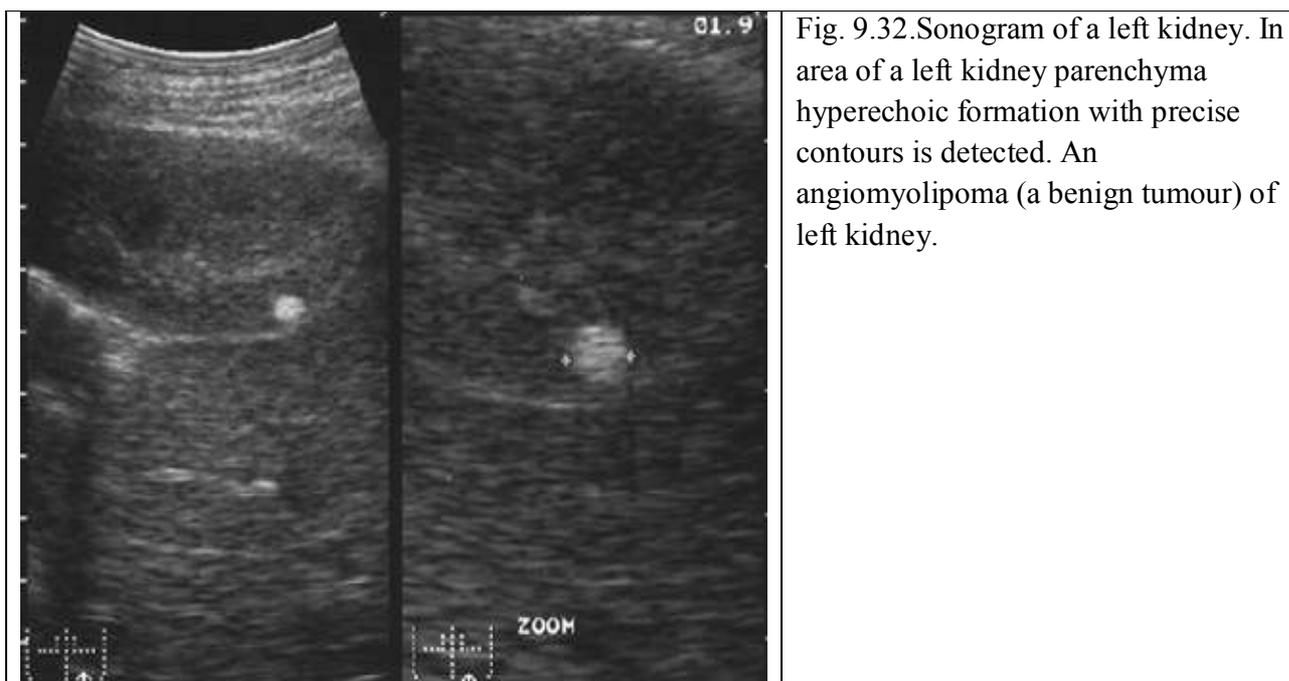


Fig. 9.31. Sonogram of a left kidney. Volumetric hypoechoic formation with rough contours in the area of the top pole of a left kidney is detected. Renal cell carcinoma.

Colour Doppler sonography using frequency shift determinations has demonstrated some utility in differentiating benign from malignant lesions. Power

Doppler sonography, which is even more sensitive to flow than conventional colour Doppler imaging, may provide additional information in characterizing renal lesions. Although US is useful in characterizing renal masses, it is inadequate in staging renal cell carcinoma.

Benign tumours of a kidney, as a rule, hyperechoic, homogeneous with smooth contours (fig. 9.32).



The CT appearance of renal cell carcinoma varies with tumour size and vascularity (fig.9.33). When large enough, these tumours appear as masses that alter renal contour or intrarenal architecture. Detection of small lesions is facilitated by rapid sequence scanning techniques during administration of contrast material because abnormal enhancement may be evident even when renal contours are normal. Heterogeneous enhancement is characteristic, but after administration of contrast medium, renal cell carcinomas typically appear less dense than surrounding renal tissue. Large intralesional vascular channels and retroperitoneal collateral vessels may also be present. Renal cell carcinomas tend to have a solid growth pattern, attenuation values of 20 Hounsfield units (HU) or higher, an increase in heterogeneous enhancement is characteristic, but renal cell carcinomas typically enhance somewhat less than surrounding renal tissue. attenuation values of at least 10 HU after administration of contrast media. Initial experience with spiral CT suggests

that this technology may offer more complete CT characterization of small indeterminate renal masses.



Fig. 9.33. Computer tomogram of the abdominal cavity at the level of L2 vertebrae. The right kidney is appreciable enlarged, contours are rough, frame is nonhomogenous. Renal cell carcinoma.

On MRI, renal cell carcinomas demonstrate variable signal characteristics depending on the degree of tumour vascularity and the presence or absence of haemorrhage, necrosis, calcification or iron particles in the tumour cells. In the absence of haemorrhage or necrosis, RCC tends to be isointense to normal renal parenchyma on both T1- and T2-weighted images. When intratumoural haemorrhage or necrosis is present, signal intensity can be heterogeneous on both T1- and T2-weighted images. Haemorrhage from a RCC may result in deposition of iron in the kidney and lower the signal intensity of the tumour on both T1- and T2-weighted images. This effect is not specific for renal cell carcinoma and may be seen with any haemorrhagic lesion or with systemic haemolysis. The differential diagnosis for a renal lesion appearing hypointense on both T1- and T2-weighted sequences also includes fibroma, milk of calcium cysts, and other calcified renal lesions. Intralesional calcifications are not well depicted on MR imaging. Renal cell carcinomas have been well depicted on postcontrast T1-weighted fat suppressed images. On gadolinium contrast-enhanced MRI scans, tumours generally enhance to a lesser degree than the surrounding renal parenchyma. Lesion sensitivity is increased when dynamic postcontrast scanning is employed.

Imaging plays an important role in renal cancer treatment decision. The decision as to the type of surgery (nephron sparing; simple or radical nephrectomy) that can be performed in patients with renal cell carcinoma is helped by imaging. Because surgery provides the only effective therapy and because survival depends

on local and distant extent, precise staging is critical for preoperative planning and prognosis.

Although CT has been the test of choice for staging renal cell carcinoma MRI appears to have a similar accuracy. Combined transverse and sagittal MRI planes are optimal for the evaluation of venous anatomy and the normal tissue – tumour interfaces.

The particular uses of MRI staging include determination of the origin of the mass, evaluation of vascular patency, detection of perihilar lymph node metastases and evaluation of direct tumour invasion to adjacent organs. On CT and MRI, diagnosis of lymph node metastases is based on detection of lymph node enlargement with nodes measuring larger than 1 cm in diameter in short axis considered abnormal. Approximately 60% of nodes measuring greater than 1 cm in transverse diameter, in the setting of RCC, however, have been shown to be inflammatory or hyperplastic in nature rather than metastatic. Lymph node enlargement due to inflammation/hyperplasia or to metastasis cannot be distinguished on the basis of imaging findings. MRI is a sensitive tool for determining the presence and extent of tumour thrombus and for demonstrating invasion of the wall of the inferior vena cava (IVC).

In the assessment of thrombus extension into the renal vein or inferior vena cava, MRI has replaced venography. In renal cell carcinoma, thrombus extends into the inferior vena cava in 4–10% of cases. Typically, tumour thrombi enlarge the renal vein and inferior vena cava and cause the density of these vessels to be heterogeneous. The accuracy in the determination of IVC thrombus is 100% on MR imaging compared to 88% and 78% for CT and ultrasound, respectively. MR accuracy in determination of renal vein thrombus is lower at 88%. On MRI tumour thrombi are usually isointense to the primary tumour.

Visualization of tumour extension to the liver, spleen and psoas muscle is also improved with MR imaging. Overall staging accuracy of 80–94% has been found with MR imaging and is similar to slightly better than that achieved with CT. The overall accuracy of CT in staging renal cell carcinoma ranges from 67–91%. When each stage is analysed separately, the accuracy of MR imaging is similar to that of CT in patients with stage I and stage II disease, but with more advanced disease (stage III and IV), particularly involving a large tumour mass, MR staging has proven superior.

Because CT is less expensive and more widely available, CT remains the preferred cross-sectional imaging procedure for the detection, characterization and

staging of renal lesions. Three-dimensional imaging and display of renal tumours using spiral CT has also recently been shown to serve as a surgical aid when planning partial nephrectomy.

MRI is reserved for those cases where CT staging is inconclusive, especially with respect to vascular extension and direct tumour invasion of neighbouring tissue or in patients with renal failure, or where there are other contraindications for the use of iodinated contrast media.

Arteriography in modern practice apply at tumours of kidneys seldom: for definition of anatomy of vessels at a planned resection of a kidney and embolization before surgery treatment.

Cysts. Simple renal cyst most often volumetric formations of a kidney. They come to light more than at 50 % of cases of patients with 50 years old are more senior. US signs of cyst include: absence of non-uniform structure, smooth and equal walls, density of contents meets to a liquid, distal acoustic enhancement (fig. 9.34).

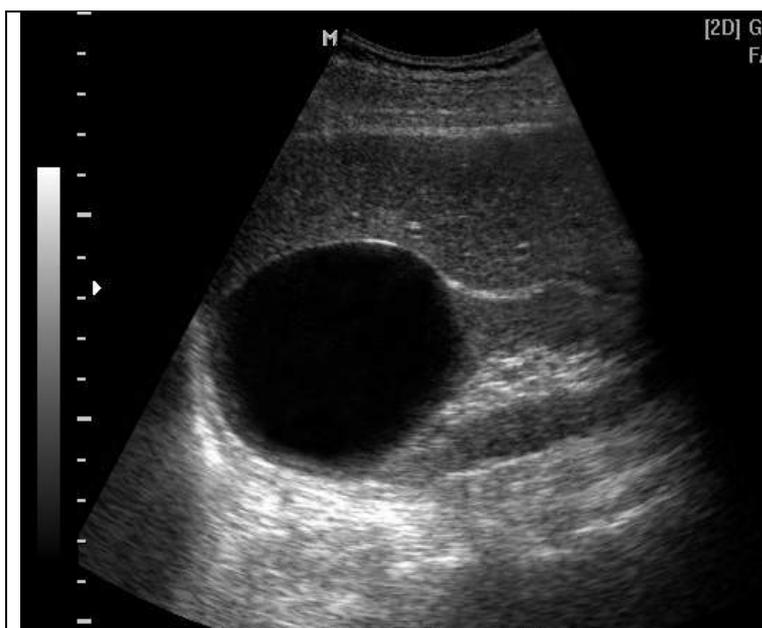


Fig. 9.34. US signs of cyst include: smooth and equal walls, density of contents meets to liquid, distal acoustic enhancement.
Cyst.

In general, renal cysts appear as nonspecific space-occupying lesions at intravenous urography, a well-defined anechoic lesion with distal acoustic enhancement at US, a non-enhancing discrete fluid density lesion at CT, and a non-enhancing well-circumscribed lesion of fluid signal intensity characteristics at MRI.

Pharmacological-ultrasonic mode with application of diuretic drug – furosemidum promotes differentiation diverticulum of calices and hydrocalix (expansion after furosemidum) from cysts.

Nephroscintigraphy shows a zone of the lowered accumulation of a preparation.

Renal trauma (fig.9.35) part of a major abdominal trauma, occurring in 8–10% of all blunt and penetrating abdominal injuries. Most blunt renal injury results from blunt impact trauma. The indications for performing an imaging assessment for renal injury after blunt trauma are controversial. Most patients with major renal injury demonstrate either gross haematuria or hypertension.

When renal imaging is considered after trauma, CT is the optimal modality. Limited IU may be performed to document the presence of two functioning kidneys if the patient's clinical status does not allow for performance of CT.

Sonography is not typically used in the acute assessment of potential renal injury, but can be used to follow previously documented renal injuries, such as extrarenal haematoma or urinoma, as well as to follow the course of post-traumatic hydronephrosis. In the acute setting portable sonography can be used to document the presence or absence of a kidney when one is not visualized by intravenous urography (IU). Further, Doppler sonography can be used to assess the patency of the renal artery and vein if a nonfunctioning or delayed-functioning kidney is seen by intravenous urography or CT scan. Generally, MRI does not have a role in the acute assessment of renal trauma. Surgical staging classifications for renal injury have been adapted to include observations from CT examination.

Grade 1. Renal trauma (fig. 9.35) refers to minor renal injuries including focal or global renal contusion; superficial lacerations that do not extend to the collecting system; small or limited perinephric or subcapsular haematomas; and segmental renal ischaemic infarcts. These grade 1 injuries comprise 75–98% of renal injury seen with blunt trauma. Renal contusions generally appear as ill-defined areas of diminished attenuation with irregular margins. Oedema associated with contusions may delay renal urine excretion focally resulting in an irregular or striated-appearing nephrogram on CT scan. Contusions may also be accompanied by disruption of collecting tubules with focal interstitial staining of the renal parenchyma with contrast-enhanced urine (renal intravasation) that may be detected on follow-up noncontrast-enhanced CT scan studies. Segmental renal infarcts are relatively uncommon and primarily affect the upper pole. Often these are associated with stretching and thrombotic occlusion of segmental intrarenal, capsular, accessory renal artery, or main renal artery branch injuries. Segmental infarcts appear as focal, well demarcated, nonenhancing regions of parenchyma that are wedge-shaped and tend to involve the renal poles. In general, grade 1 injuries are managed with observation.

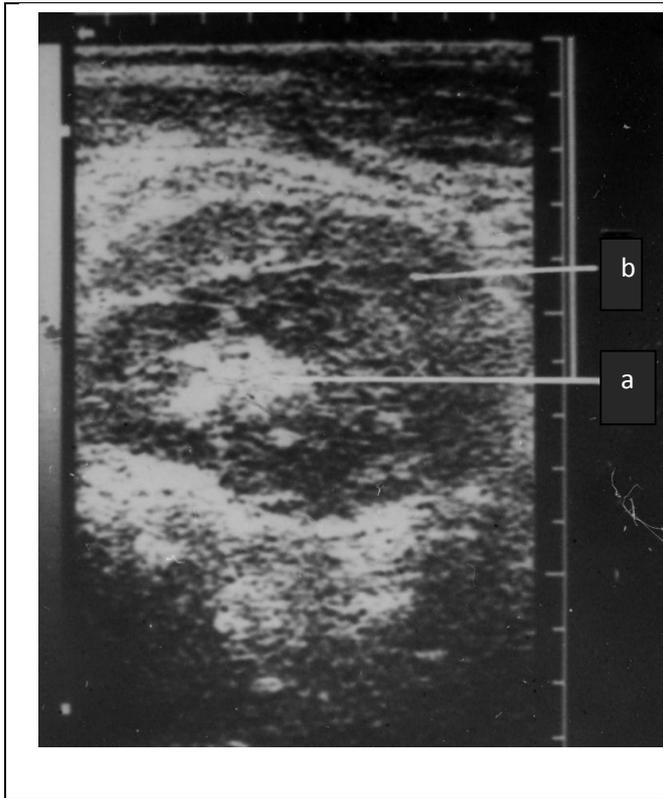


Fig. 9.35. Sonogram of kidney.
Through a capsule kidney rupture.
a – kidney; b- hematoma.
Renal trauma.

Grade 2. Renal trauma (fig. 9.36) refers to major renal injuries including deep lacerations of the renal parenchyma that extend into the collecting system, limited extravasation of urine, and moderate to large perinephric or subcapsular haematoma. It is important to distinguish renal contrast extravasation from active haemorrhage. Renal contrast leak can typically be identified arising directly from a disruption in the renal collecting system. Contrast arising from the arterial or venous haemorrhage often appears before the renal collecting system is opacified, verifying its vascular origin. The management of major renal injury typically depends on the clinical picture and evolution of the injury with time.

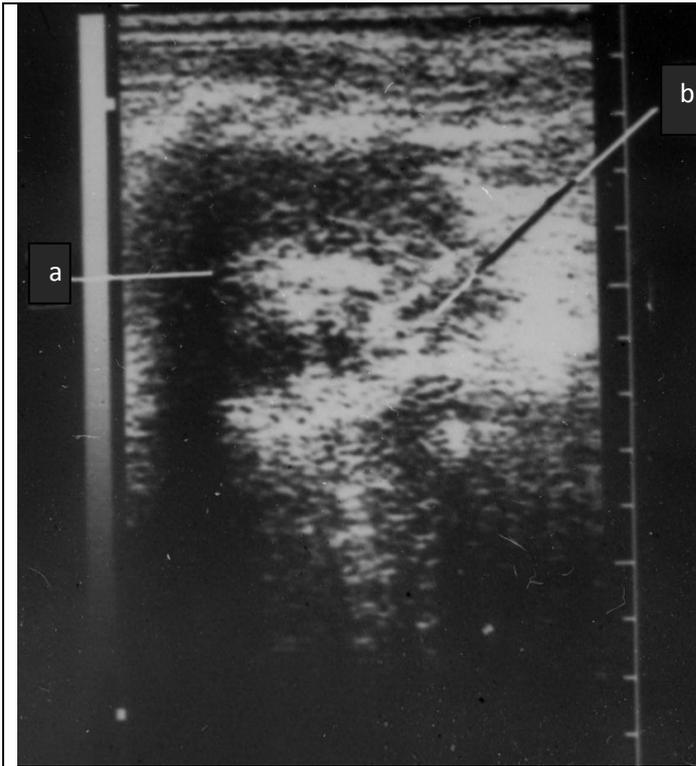


Fig. 9.36. Sonogram of kidney.
 Separation of a kidney fragment– a) kidney;
 b) fragment
 Renal trauma.



Fig. 9.37. Intravenous urography. In the field of the bottom pole of a right kidney a clump of a contrast irregular-shaped agent is detected.
 Trauma of a right kidney. Parenchyma breaks in a right kidney in a projection of the bottom and average big cups.
 Renal trauma

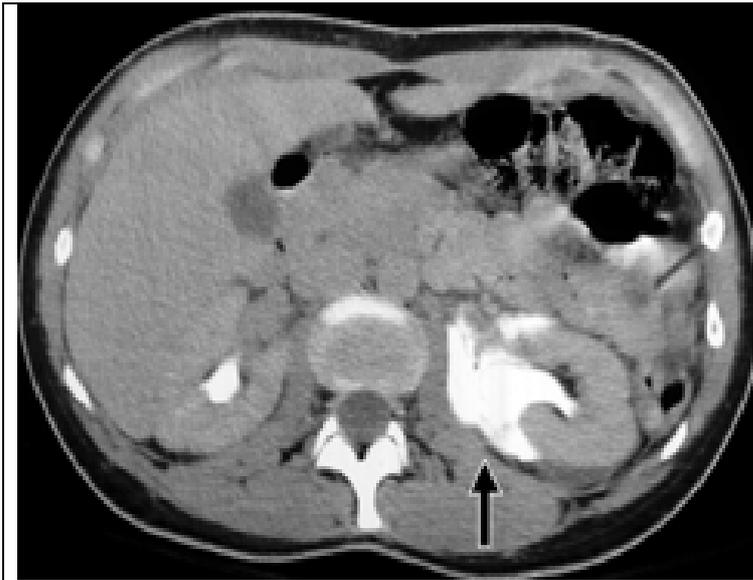


Fig. 9.38. Axial contrast-enhanced CT section through the kidneys showing extravasation of contrast (arrow) from a left kidney, due to traumatic fornical rupture. Renal trauma.

Grade 3. Renal trauma refers to catastrophic renal injuries including major renal pedicle injuries involving either the renal artery or vein, renal parenchymal fragmentation with extensive haemorrhage, active haemorrhage of renal origin, and renal pelvic or disruption of the proximal ureter. Renal artery occlusion usually results from stretching of the renal artery beyond the elastic limits of the intima during rapid deceleration, followed by renal artery thrombosis. The injury typically occurs in the proximal third of the renal artery. CT scan findings are usually diagnostic demonstrating no or only patchy peripheral renal parenchymal enhancement from intact collateral vessels. The kidney may be intact but smaller than normal owing to lack of inflowing blood and may be displaced laterally from its usual location. Angiographic confirmation of renal artery occlusion is not necessary and only serves to diminish further any chance for successful renal revascularization. Revascularization is most likely to be successful within 2 hours of injury. Delayed revascularization hours to days after injury is occasionally successful. Main renal vein injury may produce extensive perirenal haemorrhage or if thrombosed may lead to an enlarged kidney with a delayed, but progressively dense nephrogram, ongoing haemorrhage seen as patchy areas of dense contrast material surrounded by less dense haematoma. When ongoing haemorrhage is detected in haemodynamically stable patients, selective angiographic embolization is preferred to maximize renal parenchymal salvage. Bleeding in unstable patients or those who require urgent surgery for other indications is best managed operatively.

Severe renal fragmentation is considered a catastrophic injury. If CT or renal scintigraphy indicates minimal residual renal function, or if ongoing haemorrhage or gross urine leakage accompany severe parenchymal disruption, nephrectomy is required.

Hydronephrosis. Hydronephrosis, dilatation of the intrarenal collecting system (fig. 9.39). It may be divided into obstructed and nonobstructed. In the former group, the obstruction may be mechanical or functional and may occur anywhere in the collecting system. If the obstruction occurs more distally in the ureter, then hydroureter (dilatation of the ureter due to a distal obstruction) is also seen. Among the diverse causes, the more common ones include: urolithiasis, tumour, stricture, vesicoureteric reflux, congenital abnormalities (ureteropelvic junction obstruction, posterior urethral valves), and extrinsic compression (retroperitoneal fibrosis or lymphadenopathy). Nonobstructed hydronephrosis, also known as "urinary ileus", may be associated with previous obstruction or urinary infection.

In the acute state, the affected kidney is enlarged and of smooth contour. Atrophy and fibrosis are seen with long-standing hydronephrosis. Infection is a serious complication of hydronephrosis. An infected and obstructed collecting system is known as pyonephrosis, and the affected patient can quickly succumb to sepsis.

Hydronephrosis is easily detected by ultrasound (fig. 9.40). A dilated intrarenal collecting system is imaged as enlarged anechoic fluid structures, which communicate with each other to form the renal pelvis. In contrast, the multiple cysts in polycystic renal disease are separate and do not communicate with each other. Internal echoes are seen in the dilated collecting system in the setting of pyonephrosis. While ultrasound usually cannot distinguish between obstructed and nonobstructed hydronephrosis, excretory urography may provide additional information in that it may demonstrate the level of obstruction. Forniceal rupture is a complication of hydronephrosis in excretory urography; it may result from a sudden increase in urine volume due to contrast-induced diuresis.

Hydronephrosis can also be imaged by CT or MRI, though the expense of MRI precludes its use given the usefulness of the other imaging modalities for this purpose. CT is particularly helpful when imaging hydronephrosis due to obstruction from an abdominal or pelvic tumour. Not only can it depict the level of obstruction, CT can often demonstrate the cause and its extent, as well as mass effect upon the adjacent structures.



Fig. 9.39. Intravenous urography.
Hydronephrosis, dilatation of the intrarenal collecting system Intravenous urography.
Sharp expansion and deformation of cups in a right kidney. Hydronephrosis of a right kidney.

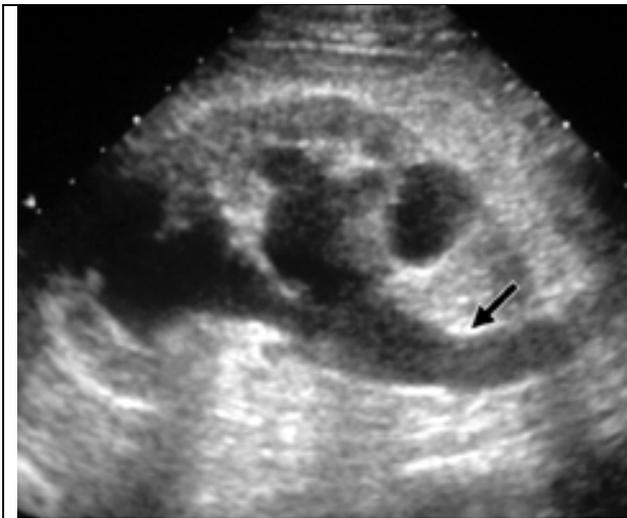


Fig. 9.40. Longitudinal ultrasound image of the kidney, showing a moderate degree of hydronephrosis and hydroureter (arrow).