CHAPTER 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 plain film of a bone (joint) in two mutually perpendicular projections is performed.

<u>Preparation for an X-ray examination.</u>

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. 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.
5. At insufficient information of x-ray film.

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 wrong form of sinus tract is defined (arrow). Chronic osteomyelitis of the femur

A*ngiography* (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; definition 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.

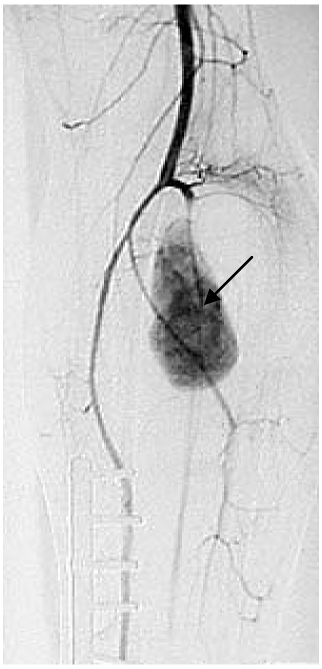


Fig. 5.2. Digital subtraction angiogram of the lower extremity Pseudo-aneurysm in the anterior tibia artery area is defined (arrow)

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.

<u>General applied radioanatomy of musculoskeletal system.</u> 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 causesblur 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 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. 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.

Compact bone is what is found on the outside of most bones. It is the hard outer layer that gives bones their smooth, white appearance. This type of bone has a much greater mass than the same amount of spongy bone, which is found in places such as joints and the ends of bones.

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 trabeculars 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 bone thready tissue forming the external contour of a bone. The compact bone presents in the cortical layer (fig. 5.4).

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

Fig. 5.4. Radiograph of humeral joint. Frontal view. Compact bone (blak arrow). Spongy bone (white arrow)

The x-ray pattern of a spongy bone rather typical and is characterized by reticular trabeculation 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.

The bones of the human skeleton can be grouped into five types: long, short, flat, irregular and sesamoid. Different types of bone have differing amounts of compact and spongy bones.

Long bones, such as those of the arms, legs, fingers and toes, are made up mostly of compact bone. These bones are longer than they are wide, so they need the added strength and support that the compact tissue can provide. As it is known, each long tubular bone consists of a diaphysis, two metaphyses and two epiphysises:

proximal and distant metaepiphysises. Each department has a characteristic X-ray pattern. The diaphysis on ax-ray film (negative) is presented as two dense stripes of a compact bone (coritical 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 epiphysises 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 bone located between the diaphysis and the epiphysial plate or epiphyseal line. Its X-ray image has plexiform structure with larger cells, than in epiphysises.

Epiphysises are terminal parts of the bone which are located behind the epiphysial plate (the epiphysial plate is found in children and adolescents) or the epiphyseal line (in adults); epiphysis is an articular end of a bone.

Short bones in comparison are roughly cuboidal in shape. They have only a thin layer of compact bone tissue. Examples of short bones include those of the wrist and ankle. Their x-ray pattern in general is identical: as the whole bone consists of spongiform substance and is zonated from different directions by a thin plate of a compact bone.

Flat bones often have two thin, parallel layers of compact bone, with spongy bone inside. These are curved bones and include the bones of the skull, the breastbone, 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.

Irregular bones do not fit into any of the other shape categories, so they are grouped together. These bones, which include the vertebrae, have thin layers of compact bone around spongy interiors.

Sesamoid bones are those bones that are surrounded by tendons. They are often found at joints, such as the knees, and they serve to protect and aid in the action of the tendon. These bones have thick layers of compact bone to protect both the bones and the tendons. The patella bone in the knee is an example of this type of bone.

<u>Joints.</u> Anatomically the joint represents cavitary, mobile bond. The most part of articulate elements has soft structure so the direct display in an x-ray is not possible. Roentgenologically 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.

The joint space is expressed on x- ray film as a stripe of radiolucency 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.5.5).

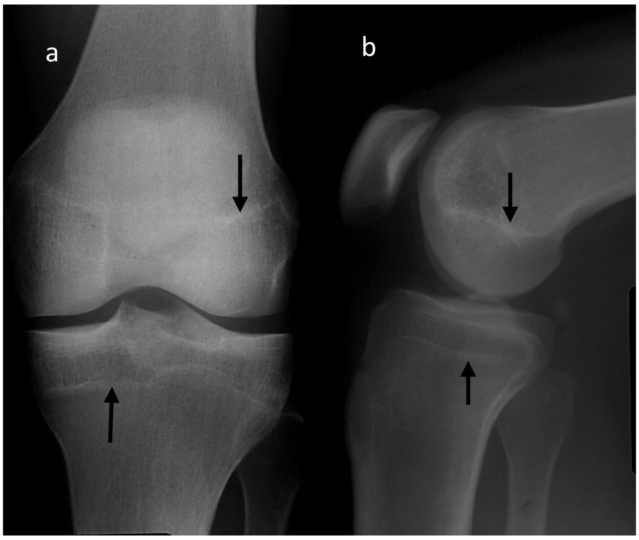


Fig. 5.5. The radiography of a knee joint in direct (a) and lateral (b) projections. The radiography belongs to an adult. Epiphyseal lines in the bones forming a knee joint are detected (arrows). Norm

<u>Age features of the skeleton.</u> 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 epiphysises, as well as all small bones, are not discernible, except distal femoral epiphysis and calcaneus, talus, 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 epiphysises of long tubular bones and other, including, small bones appear. Until complete ossification, the radiolucent strip will be detected between the epiphysis and the body of a bone. It is a cartilaginous layer, so called epiphyseal plate (fig. 5.6).

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 plate (growth plate).

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

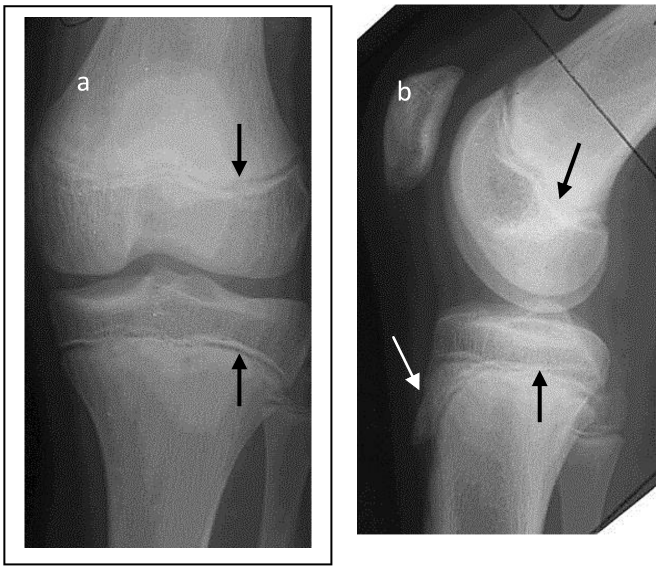


Fig. 5.6. The radiography of a knee joint in direct (a) and lateral (b) projections. The radiography belongs to a child. Zones of metaphysis-epiphysis cartilages in the bones forming a knee joint are detected (arrows) as stripes of radiolucency (epiphyseal plates). An ossification kernel is observed in the area of tuberosity of the tibia (white arrow). Norm

The final synostosis of epiphysises with diaphyses occurs at 24-25 years, in women 2-4 years earlier; x-ray film in adult on a place of the epiphyseal plates show radiopaque lines known as epiphyseal lines.

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 coritical 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 anx-ray articulate space, outlines of epiphysises 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 <u>osteoporosis.</u> 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 disappearance of separate osteal beams and augmentation of medullar cells volume; 2) thinning of the cortical bone layer, caused by disappearance of osteal trabecular 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 disappearance of osteal plates; 5) sharply emphasized cortical a layer of the whole bone (fig. 5.7).

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 separate fields is observed more often in acute processes: neuritises, fractures, phlegmons, combustions, frostbite and frequently it is an initial phase after which diffuse osteoporosis arises.

According to localization osteoporosis can be: 1) local – around the center of a

Fig. 5.7. 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

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

<u>Atrophy.</u> 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. 5.8). Atrophy, as well as osteoporosis is a convertible process. When its reason is eliminated the osteal structure can be restored completely.

Fig. 5.8. 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. 5.9).

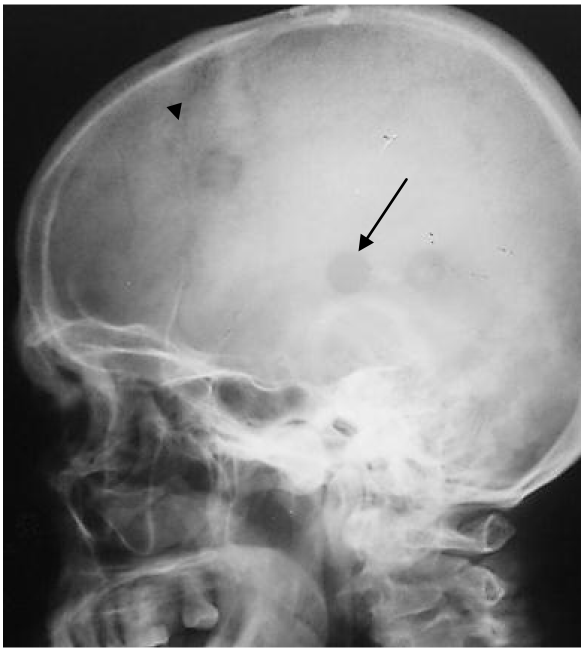


Fig. 5.9. The survey radiograph of the skull in a lateral projection. Sites of destruction have roundish form with accurate contours in bones of the skull arch (arrow). Myeloma (a tumour derived from cells in bone marrow)

Osteolysis (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 osteolysis is characteristic of some diseases of the central and peripheric nervous system, as for example, myelosyringosis, tabes, wounds of the spinal cord and large nervous trunks. Traumatic osteolysisis possible (fig.5.7).

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 a 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. 5.10). 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. Looser's zones are strongly suggestive but not diagnostic of osteomalacia. These zones are regions where too much osteoid has been laid down by the osteoblasts due to the action of parathyroid hormone. These appear as linear areas of low density surrounded by sclerotic borders. They are translucent. Osteitis fibrosa cystica is the classic bone abnormality in hyperparathyroidism (fig. 5.11). This entity is characterized by peritrabecular bone marrow fibrosis, particularly near the sites of active bone formation or resorption.
Thus the processes accompanied by decrease of osteal tissue amount are: 1) osteoporosis; 2) destruction; 3) osteolysis; 4) atrophy; 5) osteomalacia.

Fig. 5.10. Survey radiograph of shin bones in the child of 3,5 years old in a direct projection. Bones of the shins and visible departments of femurs are highly transparent (osteoporosis). Femurs are deformed, bent inside. Metaphyses of shin bones and femoral distal metaphyses are expanded. Radiological symptoms of rickets

Fig. 5.11.Radiograph of knee joint and shin. In upper part of tibia shaft is radiolucency zone whith smooth contours (arrows). The bones of shin more radiolucency than in norm. Signs of osteomalacia with osteoporisis tibia and fibula and osteotis fibrosa cystica of tibia. Hyperparathyroidism

The sets of symptoms accompanied by augmentation of osteal tissue amount are: 1) osteosclerosis; 2) periosteal reaction; 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 trabeculars and their quantity increases and, accordingly, spaces between trabeculars decreases, down to their complete disappearance.

Radiological signs of osteosclerosis are: 1) reticular structure with small cells and thickened osteal trabeculars 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. 5.12). Osteosclerosis can accompany various pathological processes: tumoral, inflammatory, hormonal disorders and poisonings, formation of osteal callosities and functional overloads. In any pathology osteosclerosisis a result of increased osteogenic activity of osteoblasts. Osteosclerosis can be a convertible process.

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 (single layer periostal 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. 5.13).

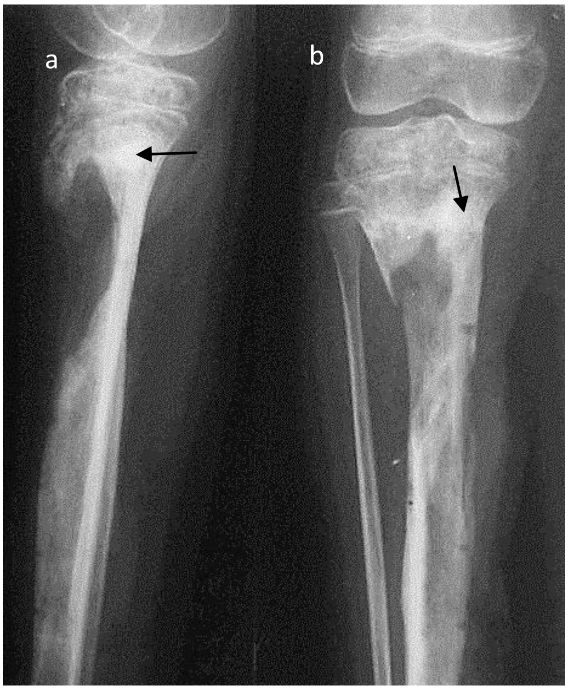


Fig. 5.12. X-ray film of the left shin in direct and lateral projections. Extensive zones of destruction in proximal metaphysis and in diaphysis of the tibia. Evident osteoscleros is around the centres of destruction (arrows). Osteoporosis of the articulate ends of bones of a knee joint. Chronic osteomyelitis of the left tibia

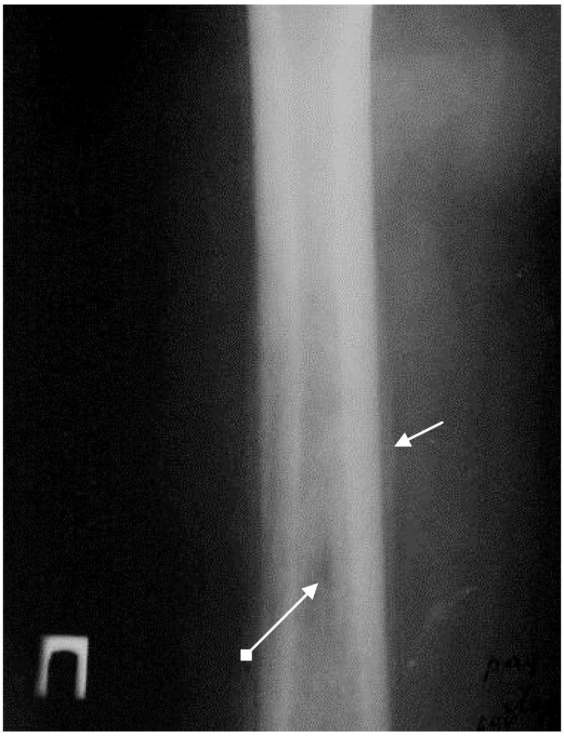


Fig. 5.13. The radiograph of the right femur in a direct projection. In diaphysis area single layer periosteal reaction is defined (arrow). Sites of destruction are in the field of diaphysis (arrow with rombus). Radiological symptoms of acute osteomyelitis

Multilamellar periosteal reaction (multilayered or lamellated periosteal reaction). X-ray shows that there are some alternating light and dark stripes along a bone, as if emanating from one point and locate done 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. 5.14).

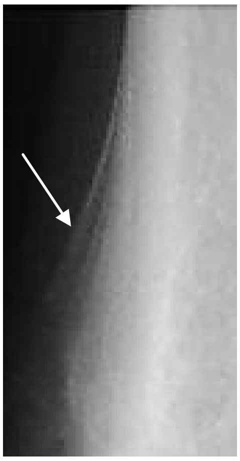


Fig. 5.14. Radiograph of a patient’s femur with Ewing’’s sarcoma. Interrupted multilayered periosteal reaction (arrow) is defined. Interrupted periosteal reactions are more often indicative of a malignant process

Solid periosteal reaction – the subsequent phase of a single layer periosteal reaction (linear periostitis) when there is a connecting of calcifications with a basic bone (fig. 5.15).

Fig. 5.15.Radiograph of the left shin in direct and lateral projections. Fibula is deformed an enlarged due to osteosclerosis and solid periosteal reaction, there is sequestrum (arrow). Chronic osteomyelitis of fibula

Spiculated-type periosteal reaction. It manifests as a formation of numerous thin processes (spiculae), growing at an angle tothe bone. These needles are ossification of newly formed tissues along the blood vessels. Is common in osteosarcoma (fig. 5.16), sometimes in metastasis (fig. 5.17).

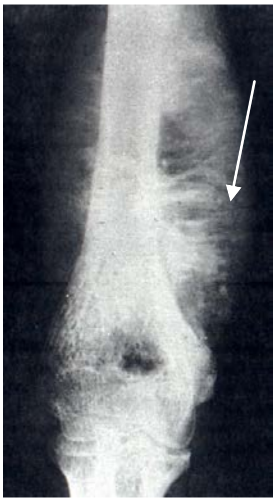


Fig. 5.16. Radiograph of the shoulder in a direct projection. Evident spiculated-type periostal reaction in distal metaphysis and diaphysis of the lower third of the humerus (arrow). Osteogenic sarcoma of the humerus

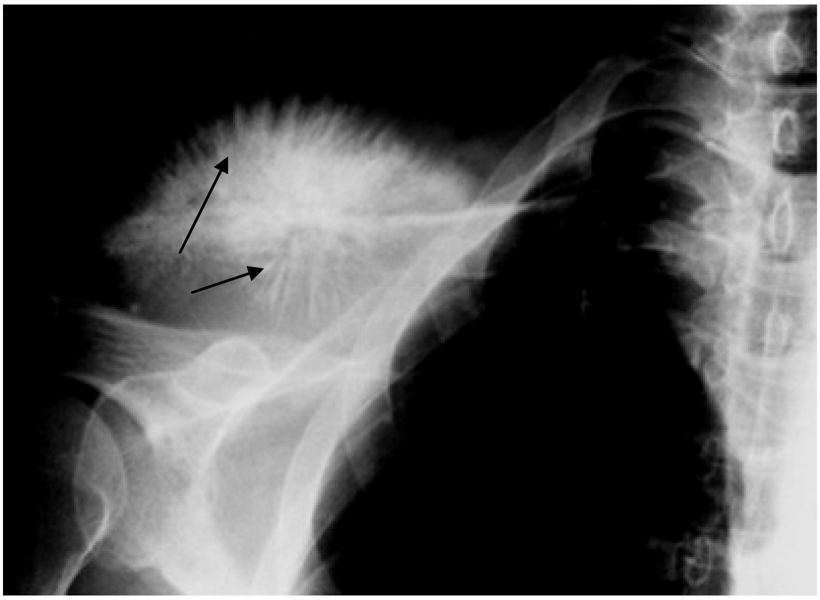


Fig. 5.17. The radiograph of a humeral joint. Frontal view. In the middle and the humeral end of the clavicle there is speculated periostal reaction (arrows). Prostate cancer metastasis in the clavicle (the diagnosis is verified by hystologycal examination)

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. 5.18).

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. 19). They can occur due to various reasons, including traumas, increased functional loads, dystrophic processes.

Necrosis and sequestration of a bone.

Osteonecrosis is a necrosis of part of the bone due to infringement trophic in bone.

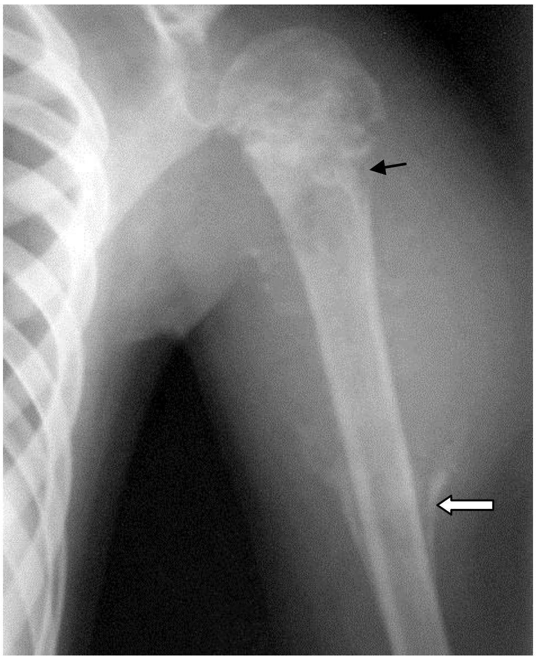


Fig. 5.18. Radiograph of the humeral bone. Frontal view. In proximal metaphysis area of the humerus there are extensive sites of destruction with indistinct contours and destruction of the cortical layer (arrow). There are periosteal reaction in the upper third of the diaphysis – Codman's triangle (a figured arrow). Osteogenic sarcoma of the humeral bone

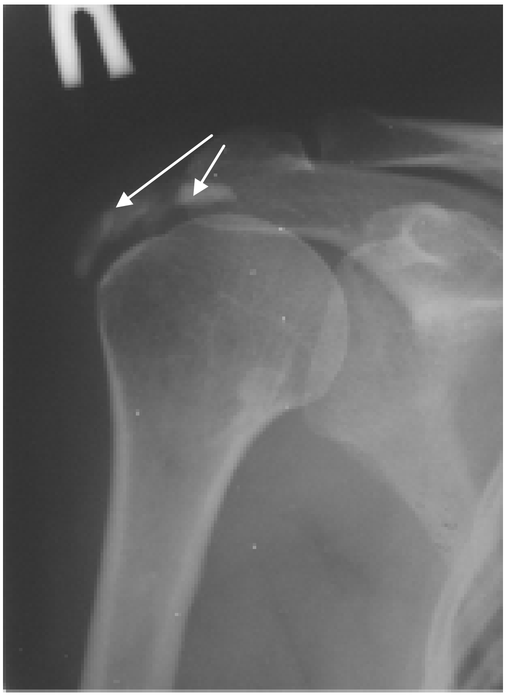


Fig. 5.19. Radiograph of the humeral joint in a direct projection. In the area of the humeral joint there is an intensive shade in a sinew projection of the supraspinatus muscle (arrow). Calcification of the sinew supraspinatus muscle

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 sequestrum. A sequestrum is a piece of dead bone that has become separated during the process of necrosis from normal bone.

Septic and aseptic necroses are distinguished. Aseptic necrosisis 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) radiolusent interval separating a healthy bone from the necrotic one; 3) osteoporosis of the surrounding healthy tissue (fig. 5.20).

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. 5.20. Radiograph of the femur. Frontal view. The femur is deformed, increased. A sequestrum (arrow) surrounded with radiolusent interval and 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.

<u>Changes of the shape of a bone.</u> 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. 5.21).

<u>Change of a bone volume.</u> Thickening (hyperostosis) is osteosclerosis plus augmentation of a bone volume. Speaking about hyperostosis augmentation of a bone diameter at an appreciable extent is meant (5.22).

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

Enostosis is enlargement of osteal tissue aside the bone marrow canal.

Inflation 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. 5.23).

Fig. 5.21. Radiograph of the femur. Frontal view. There is a leg amputation at the level of the middle third of the shaft of femur

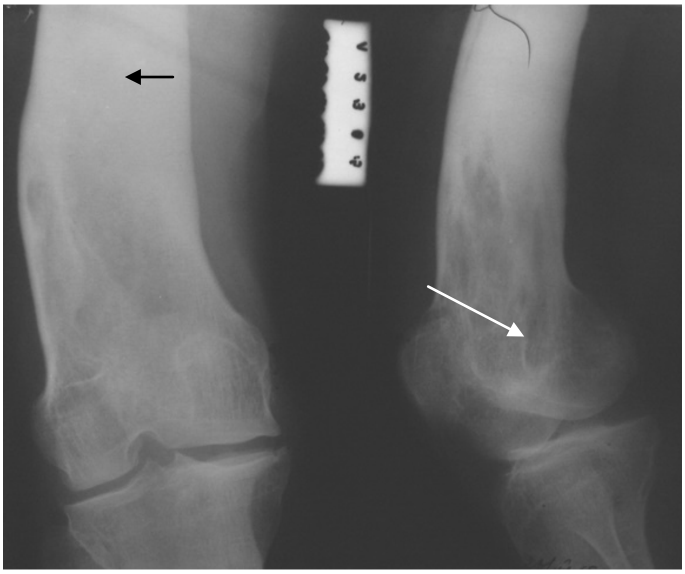


Fig.5.22. Radiograph of the hip in direct and lateral projections. Hyperostosis of the femur: the femur in the lower third of diaphysis (a black arrow) and distal epiphysis is deformed, densified (osteosclerosis), and increased in sizes. Sites of destruction in distal metaphysis (a white arrow) are detected as well. Chronic osteomyelitis of the femur

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 (fig. 5.24) and incomplete (partial). Congenital absence of a joint (articulate space) can occur.

Fig. 5.23. 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 reation are absent.
Osteoblastoclastoma (Giant cell tumour) of the ulna

In that case we speak about a concrescense which has typical localization – fine joints of extremities, vertebra.

Change of an articulate ends. 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).

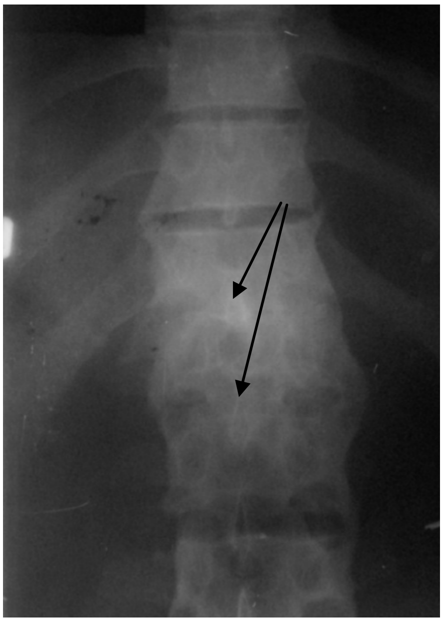


Fig. 5.24. Radiograph of lumbar and chest departments of the backbone in a direct projection. The ankylosis Th12, L1 and L2 of vertebras (arrows) is detected.
Ankylosing tuberculous spondylitis of the backbone

Destruction of articulate ends of bone. This sign is characterized by destruction of bones localized within the limits of the articulate capsule and near to it outside the joint (fig. 5.25).

Erosions arise in an area of local demineralisation beneath the cortex, which is progressively resorbed, leaving irregular underlying trabeculae. The destroyed area increases in size and, as pannus spreads over articular surfaces, the entire articular cortex may bedestroyed, leaving a destroyed bone end.

Deformation of articulate ends of bones. As a rule deformation of the articulate ends and articulate surfacesis the basic sign of arthrosis. Deformation can look like: flatteningof the glenoid cavity as well as articular head; recess of the glenoid cavity; excrescence on the edges of the glenoid cavity; osteophytosis – osteal growths along the edges of articulate surfaces (fig. 5.26).

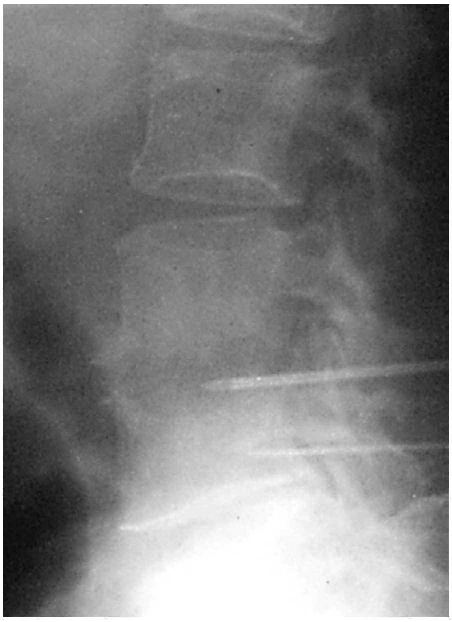


Fig. 5.25. The radiograph of lumbar part of the backbone in a lateral projection. There is a destruction of adjacent bodies L4-L5 of vertebras. Puncture of the damage area detects needles

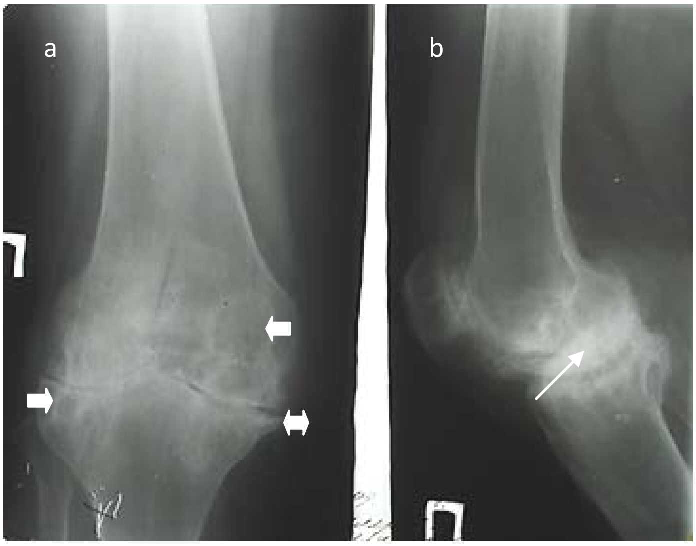


Fig. 5.26. Radiographs of the knee joint in direct (a) and lateral (b) projections. Narrowing and deformation of the joint space, subchondral sclerosis (arrow), cysts formations (figured arrows), osteophytosis (a double arrow) are detected. Osteoarthritis of the right knee joint

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 doseincreases 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}technetium-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 metabolism: destructive lesions such as osteomyelitis and tumors, arthritis, and areas of growing bone (fig. 5.27).

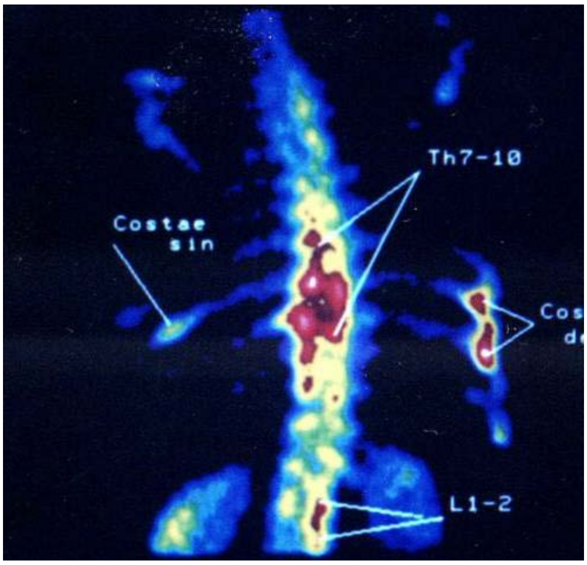


Fig. 5.27. Radionuclide bone imaging (osteoscintigraphy), with ^{99m}Tc-methylene diphosphonate. Hyperfixing in chest and lumbar departments of the backbone; in ribs from both parties. Signs of metastases of a malignant tumour in a bone

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-methylene diphosphonate 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'sdesease and limphosarcomas, bone aseptic necrosis, osteomyelitis, cancer metastases and primary tumors of musculoskeletal system (fig. 5.28 and 5.29), bone marrow edema, inflammatory processes in a bones and joints (fig. 5.30).

Fig. 5.28. Sagittal T1WI of the spine. Determined multiple metastases in the vertebrae (some metastasises are specified by arrows), giving a low-intensity magnetic signal due to replacement normal bone tissue by tumor. Because fat bone marrow with high magnetic signal changes to low signal of tumor metastases

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 (fig. 5.31 and 5.32);

• changes of synovial membrane;

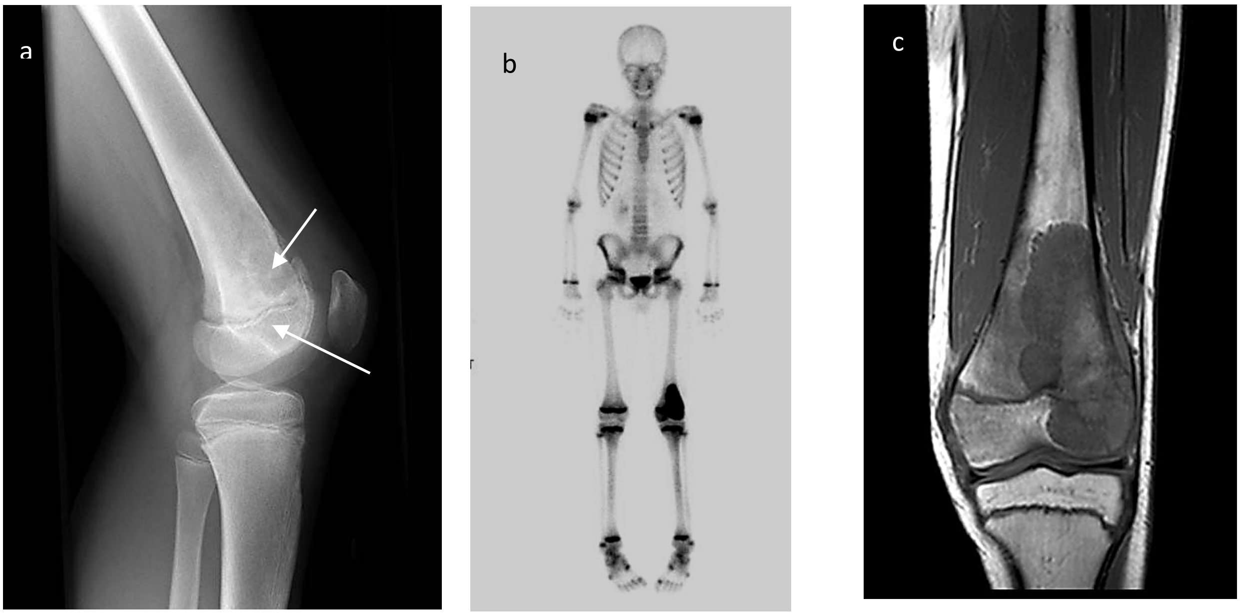


Fig. 5. 29. Radiological signs of osteogenic sarcoma distal metaphysis and epiphysis of femur [109]:

a) Radiograph of femur. Lateral view. There is a zone of lytic lesion in the distal metaphysis and epiphysis of femur (arrows)

b) Bone scintigraphy with technetium-99m-methylene diphosphonate (MDP) show the zone of hyper-fixation in distal metaphysis and epiphysis of femur

c) MRI. T1 WI. Frontal view. Determined hypo-intense area in distal metaphysis and epiphysis of femur with more large size than on radiograph

- articular cartilages (fig. 5.33);
- ligaments and tendons (fig. 5.34);
- subchondral bone marrow.

MRI is the most exact method of evaluation of these structures. For example, according to the published comparisons, x-ray filming detects5-10 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.

In MRI with intravenous opacification a short (up to 15 min) stage of intensifying of rich vascularized intraarticulate 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 intraarticulate 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.

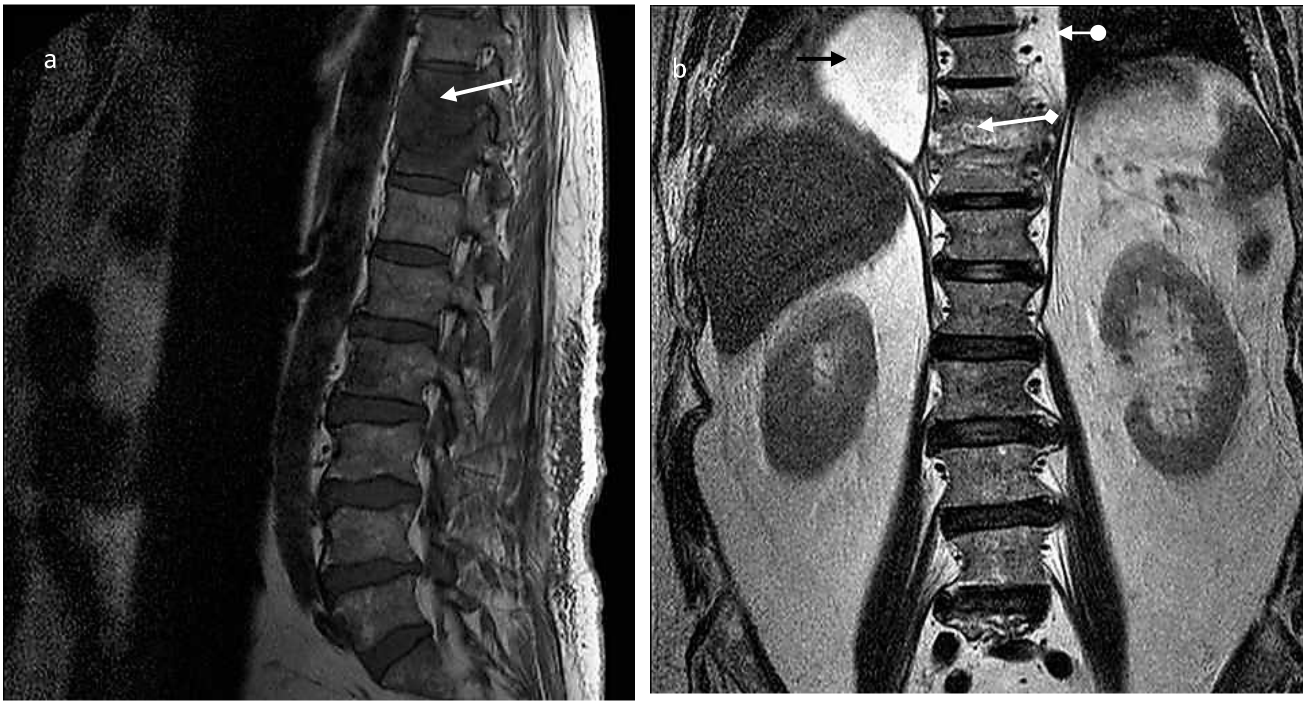


Fig. 5.30. a) T1W image in the sagittal projection.b) T2W in the coronal projection:
a) the signal from the vertebraes bodies Th10 - Th11 decreased at T1 scans. The apposing surfaces of these bodies are destroyed (arrow). b) The height of vertebral corpuses Th10 - Th11 reduced. High signal of the intervertebral disc Th10 - Th11 (arrow with rhombus). It is adjacent heterogeneous liquid component of irregular shape (arrow hith circle) surrounding edematous tissue. In the right pleural cavity on an adjacent plot has rounded form a homogeneous liquid component (black arrow). MRI signs of spondylodiscitis and pleural effusion

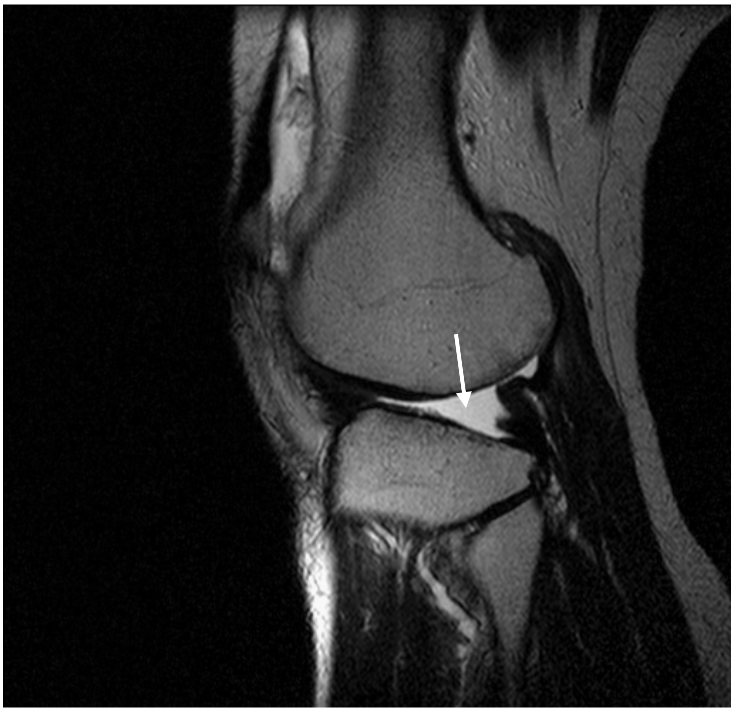


Fig. 5.31. MRI of the knee joint. T2 WI. Sagittal view. In the cavity of the knee joint increased amount of fluid is determined with high magnetic signal (arrow). MRI signs of arthritis of the knee joint

Fig. 5.32. MRI of the knee joint in sagittal plane. T2 WI. There are a considerable number of homogeneous effusion in the popliteal fossa as a plot with increased signal intensity (arrow). MRI signs of bursitis of the knee joint

Fig. 5.33. Spondylosis of the lumbosacral spine: a) radiograph of the lumbosacral spine in the lateral projection. A reduction in the height of the intervertebral disc L2-L3. Retrodisplacement L2 vertebra; b) computed tomography – a fragment of 3D - reconstruction in the sagittal plane of the lumbar and sacral spine. A reduction in the height of the intervertebral disc L2-L3. Retrodisplacement L2 vertebra; c) MRI - T2 WI lumbar and sacral spine in the sagittal plane. Determined intervertebral hernias L5-SI, L4-L5, L3-L4, L2-L3, narrowing the spinal canal (arrows). MRI provides the definitive diagnosis

The majority of MR-tomographs at best can give only a series of images during different moments of this or that movement.

Fig. 5.34. MRI. T2 WI. Section in the sagittal plane. The high magnetic signal from the anterior cruciate ligament near the site of attachment to the tibia (arrow). Signs of partial rupture of the anterior cruciate ligament in knee joint

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 (fig. 5.35);
- accumulation of fluid in soft tissues (fig. 5.36 and 5.37);
- traumatic tendon and muscles injuries (fig.38);
- intraarticulate exudates (fig. 5.39);
- 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.

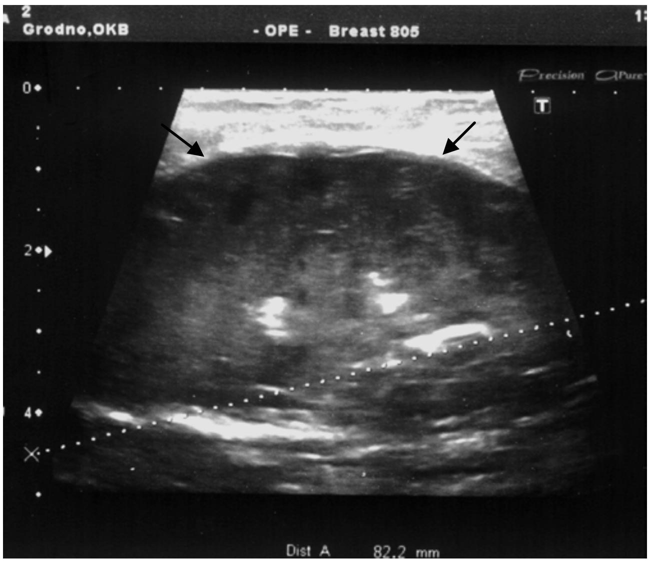


Fig. 5.35. In soft tissues of the shin is defined hypoechoic, heterogeneous, rounded mass (arrows) with hyperechoic inclusions within. In the external contour of this mass has ill-defined zones. Histological examination defined chondrosarcoma

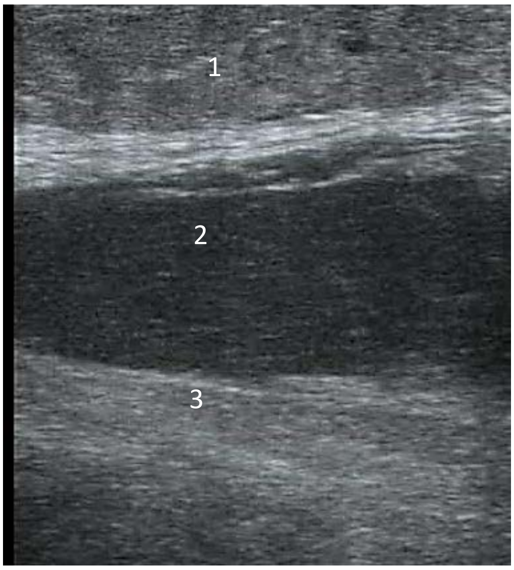


Fig.5.36. Ultrasound. B-mode.
Between muscles of the bottom third of hip is defined hypoechoic zone (2). 1) Musculus rectus femoris. 2) Pus.3) Musculus vastus intermedius. An intermuscular abscess in the hip

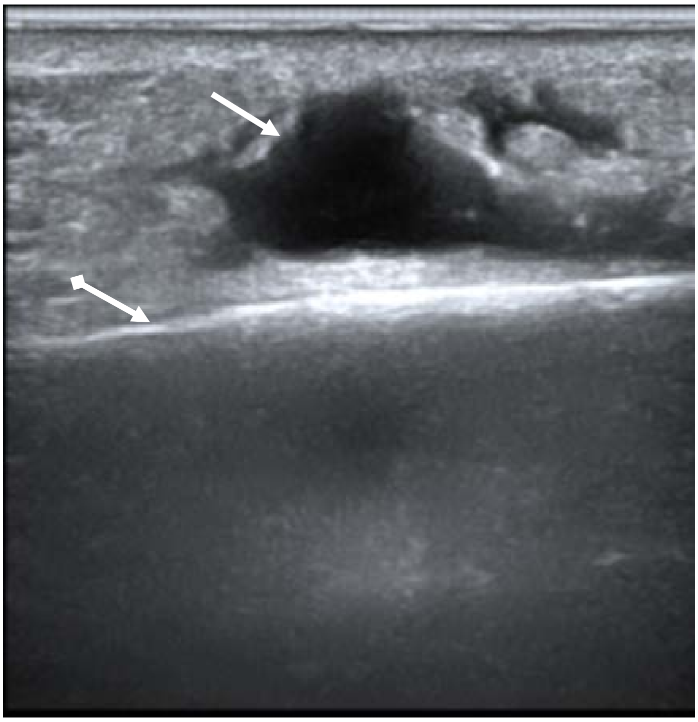


Fig.5.37. Ultrasound. B-mode. Haemorrhagic effusion in a shin which give the hypoechoic zone with irregular contour (arrow). Tibia (arrow with rhomdus)

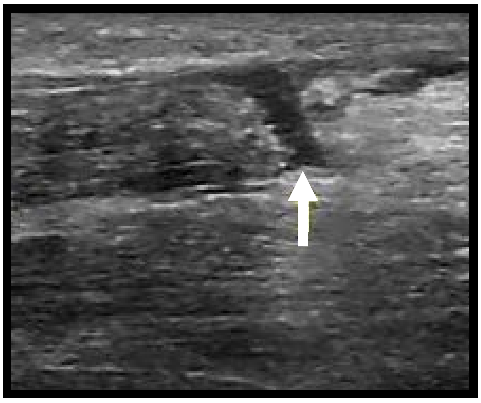


Fig. 5.38. Ultrasound. B-mode.
Hypoechoic the zone crossing Achilles tendon (arrow). Achilles tendon tear [95]

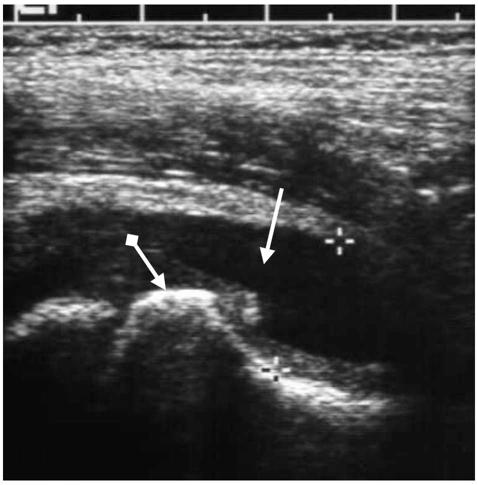


Fig. 5.39.Sonography. Depiction of hip joint: obvious echo-free joint effusion (arrow). Proximal epiphysis of femur (arrows with rhombus). Coxitis [96] .

5.6. Radiology at traumatic damages of a musculoskeletal system

Fractures and dislocations of bones.

Complete inconformity of articulate surfacesis 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. 5.40).

In the backbone a dislocated vertebra is the overlying one. Reading X- ray

Fig. 5.40. The radiograph of the left ulnar joint in lateral projections. Full discrepancy of joint surfaces of an ulnar joint due to dislocation of forearm bones with their displacement backwards (arrow)

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. 5.41 and 5.42).

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. 5.43).

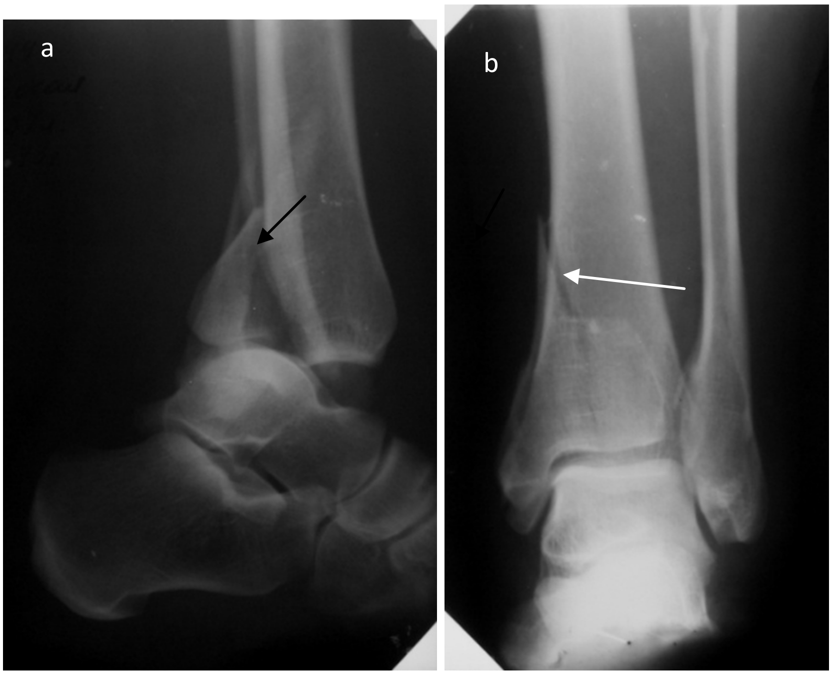


Fig. 5.41. Radiographs of the shin in lateral (a) and direct (b) projections. In the area of distal metaphysis and epiphysis of tibia there is the line of fracture (arrows) located under a corner in a vertical direction, dislocation of the back tibia fragment backwards. Discrepancy of joints surfaces in the ankle joint (a white arrow). Intrajoint fracture of tibia back edge, dislocation of the foot backwards

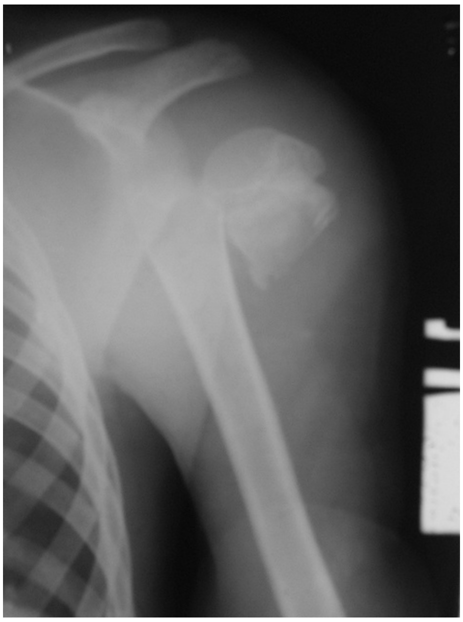


Fig. 5.42. The radiograph of the humeral joint in a direct projection. In the area of the surgical neck of the humerus fracture with cross-section displacement to lateral direction (on the width of metaphysis). Proximal fragment is displaced downwards. Total discrepancy of surfaces in the humeral joint. Fracture of the humeral bone surgical neck. Back dislocation of the shoulder

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

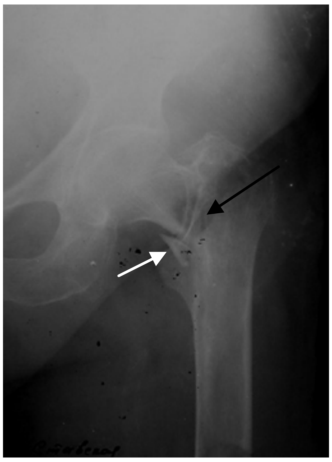


Fig 5.43. The radiograph of the hip joint in a direct projection. The line of fracture in the form of consolidated osteal tissue in the area of a femur neck (a black arrow) with a small fragment (a white arrow) is detected. Impaction fracture of the femur neck

Dislocated fragment can be 1) lateral along a diameter of a bone (displacement), 2) longitudinal in relation to longitudinal bones: 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, 4) quite often typical traumas evoke so-called 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) intraarticulate and 2) extraarticulate fractures are distinguished (fig. 5.44, 5.45, 5.46, 5.47, 5.48, 5.49, 5.50).

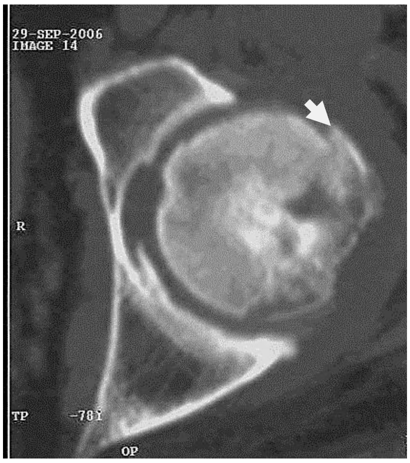


Fig. 5.44. CT-scan of the left hip joint. A fracture line in the area of femoral neck medial department (arrow). Fragments dislocations are insignificant: the bone contour is irregular along the fracture line

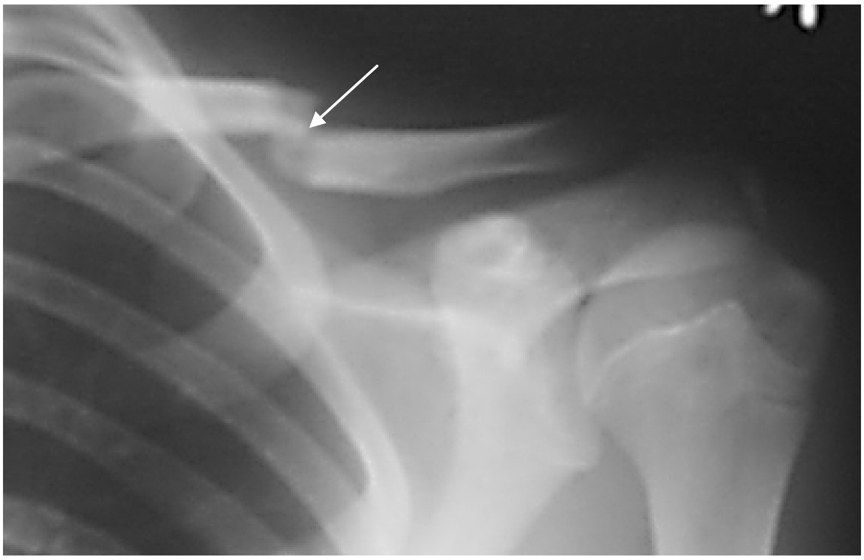


Fig. 5.45. The radiograph of the humeral joint in a direct projection. A line of fracture and cross-section fragments displacement in the area of the clavicle body (arrow). Clavicle fracture is detected

Fig. 5.46. 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

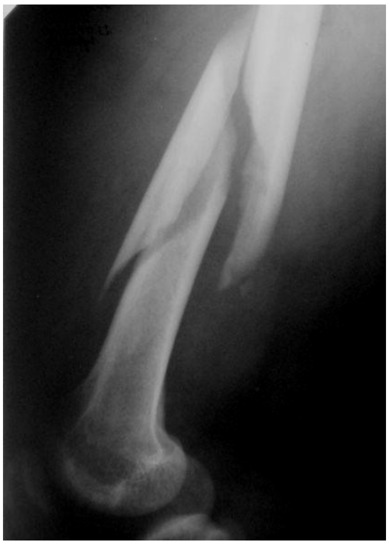


Fig. 5.47. Radiograph of the femur in a lateral projection. Spiral fracture of the femur diaphysis is detected

Intraarticulate fractures usually localize behind the place of joint capsule attachment, i.e. near an articulate 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. 5.51).

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 lime depositions usually are detected on radiographs 1,5-2 weeks after a fracture, in adults in 3-4 weeks. Complete osteal consolidation occures not earlier than in 3-7 months. Approximately at the same time

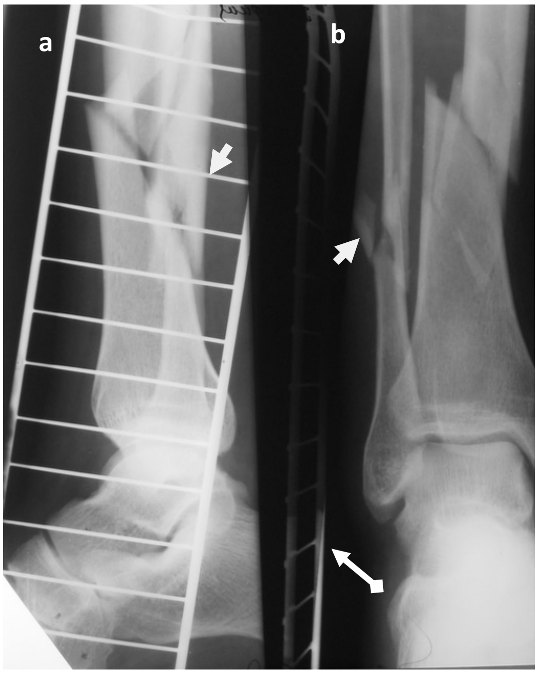


Fig. 5.48. Radiographs of the shin in direct (a) and lateral projections (b). Spiral lines of fracture in the tibia and fibula diaphyses are detected. Displacement of bone fragments in a cross-section direction. There are additional bone fragments in the affected area (white arrows). The image depicts wire transport splint in a lateral projection (arrow with rhombus). Splintered tibia and fibula fractures are detected

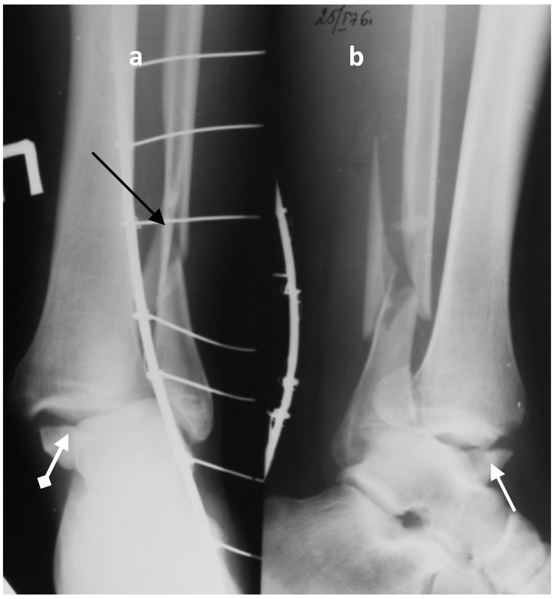
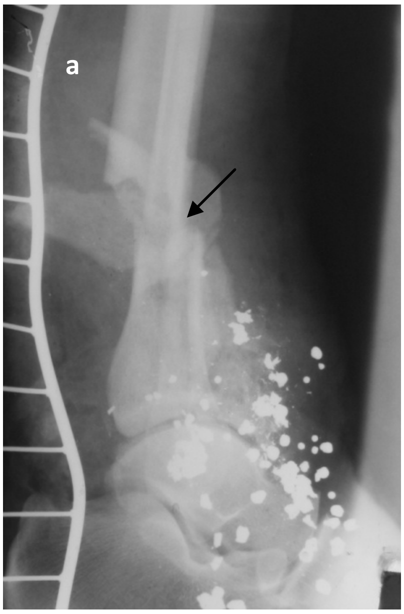


Fig. 5.49. Radiographs of the shin in direct (a) and lateral (b) projections. A fracture line in distal third of diaphysis area of fibula with a bone splinter (a black arrow). The internal ankle-bone fracture line is located diametrically (a white arrow). Lateral subluxation of the foot (black diamond-shaped arrow). Fracture of the internal ankle-bone (intrajoint) and splintered fibula fracture with lateral subluxation of the foot



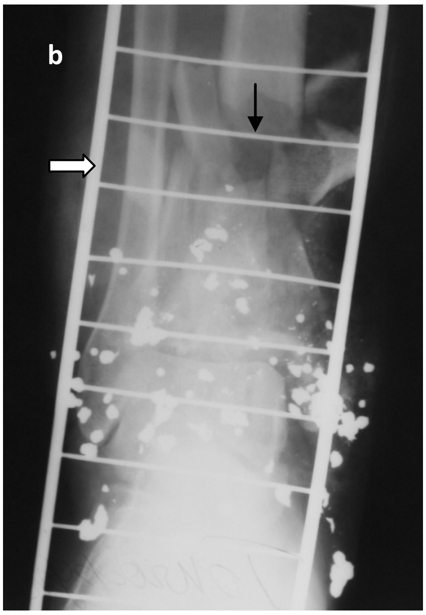


Fig. 5.50. Radiographs of the shin inlateral (a) and direct (b) projections. In the area of the ankle joint in both projections there are multiple small the round high-intensity foreign bodies (gun shot). Fracture lines in distal thirds of tibia and fibula diaphyses (black arrows), and also in distal 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

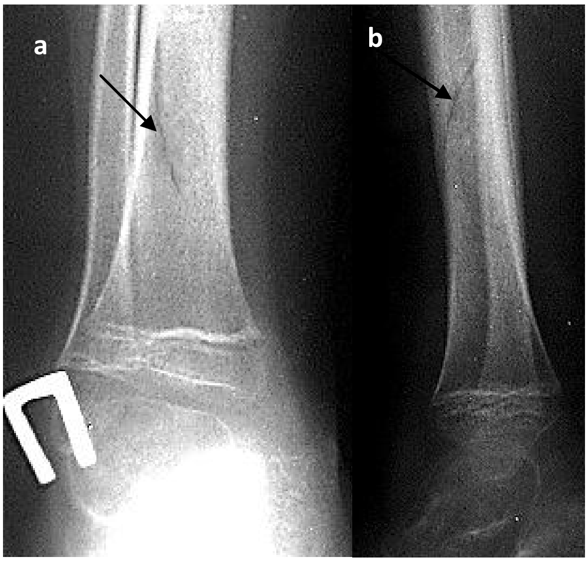


Fig. 5.51. Radiograph of the right shin in direct (a) and lateral projections (b). The line of fracture lies in tibia diaphysis area, extending from a front-exterior contour of a bone to backwards-interior one, not reaching an opposite contour (arrows). Displacement of fragments is absent. Incomplete fracture of the right tibia diaphysis is detected

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. 5.52, 5.53).

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. 5.54).

Fig. 5.52. The radiograph of the elbow joint area, 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)

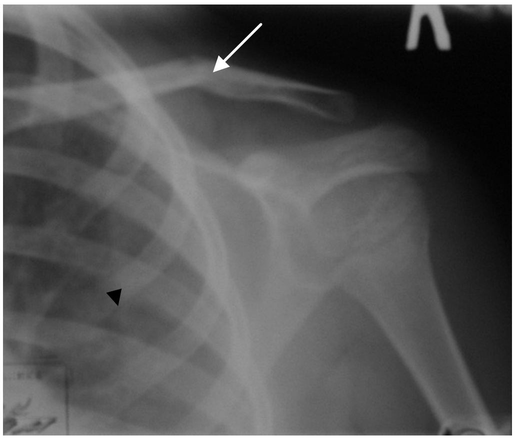


Fig. 5.53. The radiograph of the humeral joint in a direct projection. Fracture of the clavicle body with fragments displacement. under a corner opened downwards (arrow). The line of fracture is not detected. A healing stage. Solid fracture of the clavicle body.

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.

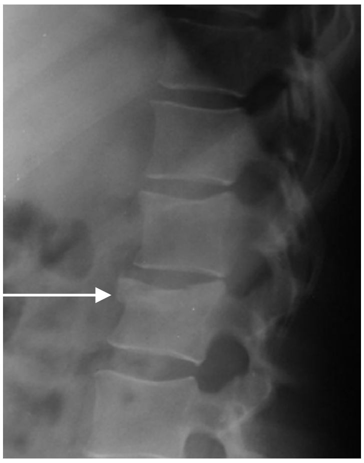


Fig. 5.54. The radiograph of lumbar department of the backbone in a lateral projection. Vertebra displacement is absent. Anterior compression of the body of the third lumbar vertebra is detected (arrow)

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: aplastic bowing fracture 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 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 epiphysiolysis. 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.5.55, 5.56, 5.57).

Fig. 5.55. 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. Plastic bowing fracture of the radial bone and classic green-stick fracture of ulna diaphysis

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. 5.58).

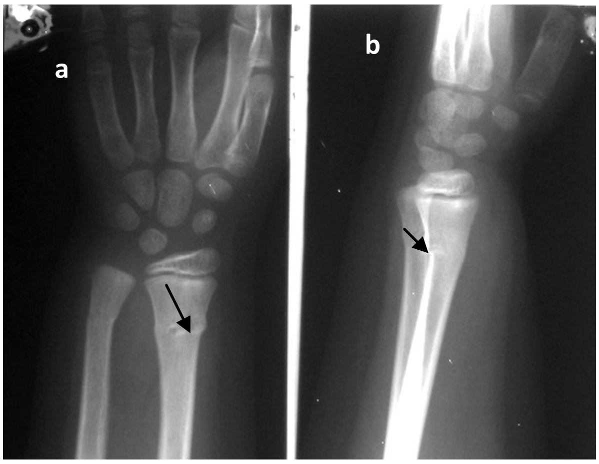


Fig. 5.56. Radiograph of the radiocarpal joint in direct (a) and lateral (b) projections. Consolidation of osseal structure of radial bone metaphysis and deformation of its surface (a white arrow). Torus fracture of radial bone distal metaphysis of radius

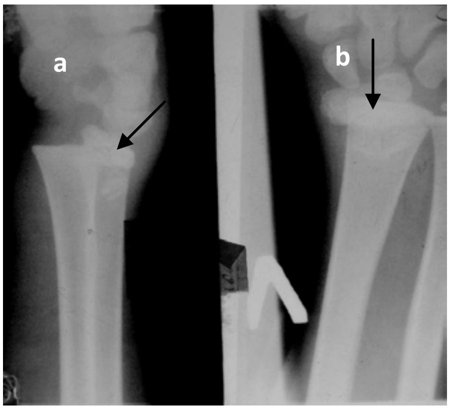


Fig. 5.57. The radiograph of the left radiocarpal joint in lateral (a) and direct (b) projections of a 14-year-old child. In direct and lateral projections there is a displacement of radial bone ectad and entad (arrows). Traumatic epiphysiolysis with radial bone distal epiphysis displacement

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:

• 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 by radiograph 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 tendonare 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.

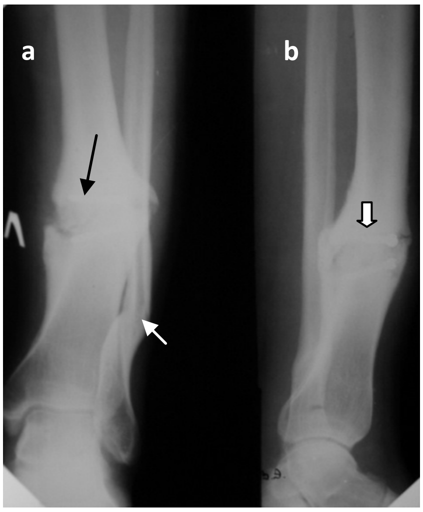


Fig. 5.58. X-ray of shin bones in direct and lateral projections. Fracture edges near to a fracture line of tibia are condensed. Osteosynthesis in the form of metal staples, connecting tibia fragments is visible (figured arrow). A false joint in tibia (a black arrow) and incorrectly fused fracture in the distal fibula with well generated callus (a white arrow)

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 scintigraphy. 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 by radiography 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. Seqvestrum is detected usually not earlier, than a month after the disease beginning.

3) Changes of soft tissues are detected by ultrasonic scanning; subperiosteal abscessesis 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 ofosteomyelitis are single layer periostal 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 (fig. 5.59).

Fig. 5.59. Radiograph of the first finger of the hand. Osteoporosis, consolidation and increase in soft tissues in area of distal phalanx is indicated. It is destruction of a bone of distal phalanx of the first finger (arrow). Panaricium of the first finger of the hand

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 ostitis. Sequesters are formed. Wide spread osteosclerosis in osteomyelitis indicates the transition of process in chronic one; solid periosteal reaction is characteristic of it as well (fig. 5.60).

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 (fig. 5.61, 5.62).

Fig. 5.60. Radiograph of the shin in a direct projection. The tibia is deformed and enlarged, symptoms of necrosis are defined: sequestral cavity with sequestrum (arrow), surrounded by the extensive zone of osteosclerosis. Chronic osteomyelitis of the tibia

Fig. 5.61. 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 (5.62); in the backbone inflammation of intervertebral disks and soft tissues is called spondylitic phase.

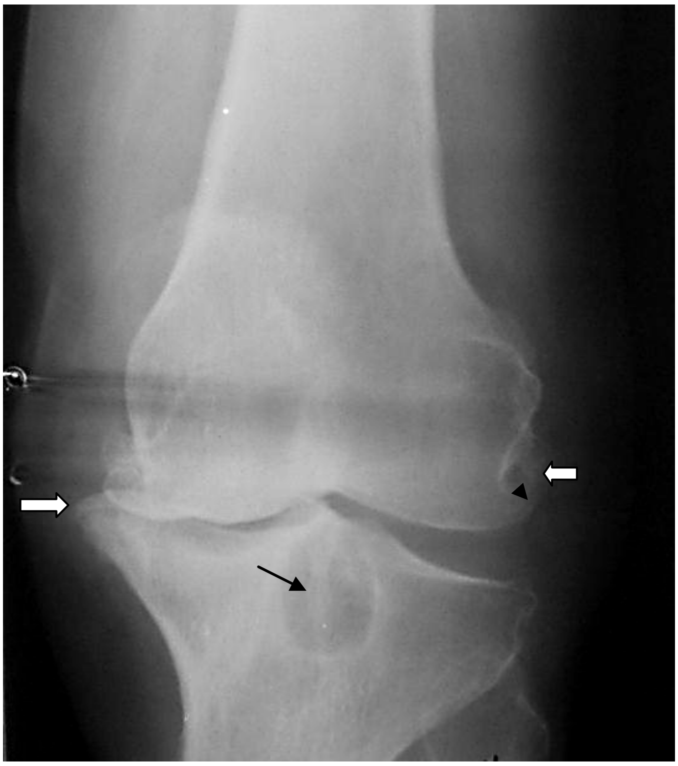


Fig. 5.62. The radiograph of the knee joint in a direct projection. In area of tibia proximal epiphysis a site of destruction with indistinct contours (arrow) is detected. There is a narrowing of the knee joint and its deformation. Subchondral sclerosis is detected. There is a marginal osteophytes (figured arrows). Tubercular ostitis of the tibia. Osteoarthritis of the knee is detected

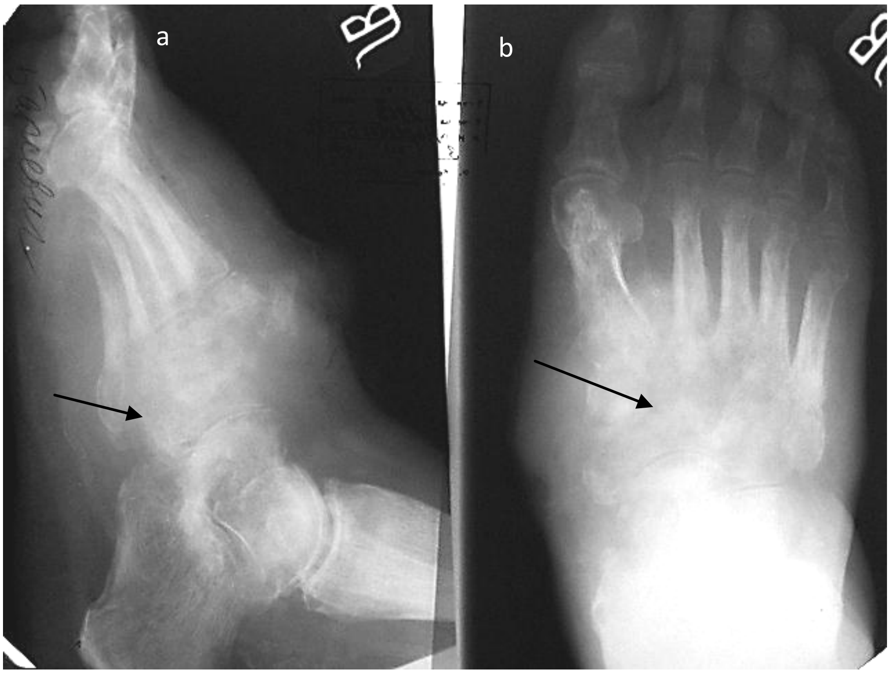


Fig. 5.63. The radiographs of the foot in lateral (a) and direct (b) projections. Destruction of naviculare, cuboideum, cuniforme bones and proximal epiphyses metatarsi bones (arrow), indistinct contours of joint surfaces of these bones. Osteoporosis of calcaneal and ankle bones. Tubercular ostitis of the foot

After decrease of inflammations there comes the third phase (postarthritic stage), for which gradual replacement of the inflammatory granuloma by a cicatrical tissue is typical (fig. 5.64). Localization of the centers is typical for tuberculosis: 1) body of vertebra, 2) flat bones, 3) epiphysises of tubular bones. The centers in epiphysises are frequently large and contain sequesters from spongiform osteal

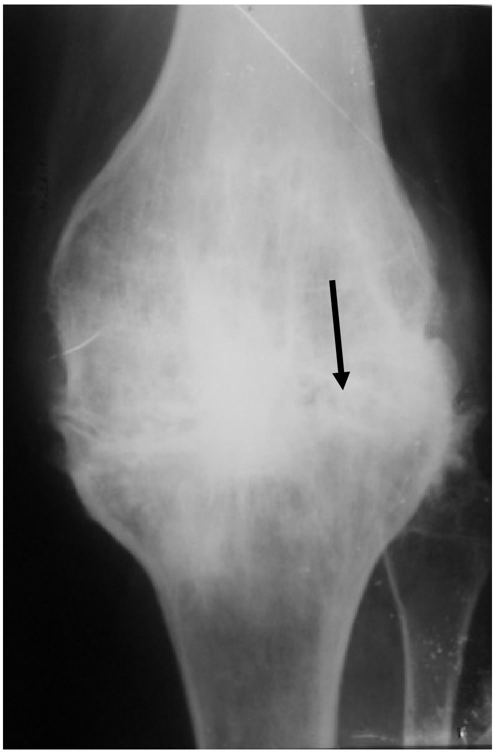


Fig. 5.64. The radiograph of the knee joint in a direct projection. The image of the joint space on the large extent is absent (arrow), subchondral sclerosis, osteophyts is detected. Tubercular ostitis in postarthritic stage. Ankylosis of the knee joint

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 osteoporosis of bone, and soft-tissue swelling will be evident around the affected interphalangeal joints. Some loss of cartilage may also be seen (fig. 5.65).

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 coritical layer.

Congenital lues manifests in the first months after the birth.

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

Three stages osteochondritis are distinguished: the 1ststage –the area of

Fig. 5.65. 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). Rheumotoid arthritis

epiphyseal cartilage preliminary calcification extends up to 2-3 sm and becomes more intensive; the 2ndstage – the border of this area from the side of metaphysis aquires rough, serrate contours, transversal light stripy appears under it (Wegner's line); the 3rdstage – the area of preliminary calcification is destroyed irregularly, therefore pathological fractures are possible. In patients the processes of ossification are accelerated. In children syphilitic phalangitisis 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 (fig. 5.66). 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).

Fig. 5.66. Radiograps 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 aquired syphilis of shin bones (the tertiary period)

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. Other wise 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 nearby the bone 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 distinguish 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 distinguish able 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 lymh-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 coritical 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. 5.67).

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 multilayered periosteal reaction is characteristic (fig. 5.68). Some sarcomas have a predilection for certain bones. For example, chondrosarcomas favor the pelvis (fig. 5.69).

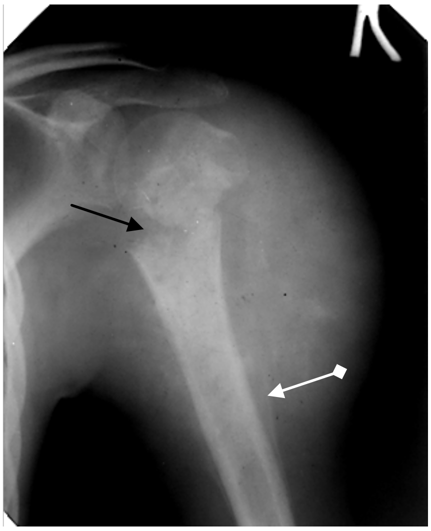


Fig. 5.67. Radiograph of the humeral joint in a direct projection. In area of proximal epiphysis and humeral bone metaphysis a there is destruction with pathological fracture and cross-section displacement of fragments (arrow). Codman’s triangle (arrow with rhombus). Osteosarcoma of the humeral bone with pathological fracture

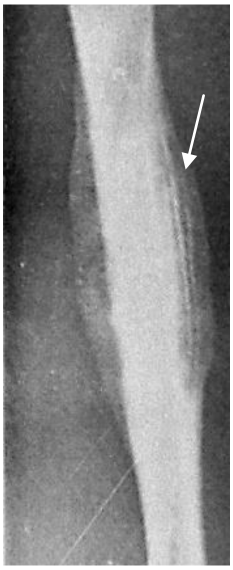


Fig. 5.68. Radiograph of the hip. Destruction of cortical layer of femur diaphysis is detected as well as irregular interrupted laminated (multilayered) periosteal reaction (arrow). Ewing's sarcoma of the femur

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.

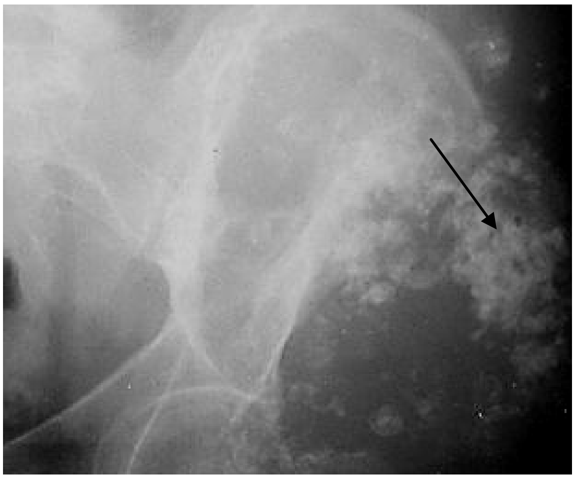


Fig. 5.69. Radiograph of the pelvis in a direct projection. In the area of the iliac bone there is an extensive destruction zone with indistinct contours, involving the cortical layer, pathological bone tissue with non-homogenous structure (arrow). Chondrosarcoma of the left iliac bone is detected

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. 5.70).

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. 5.71).

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. 5.72).

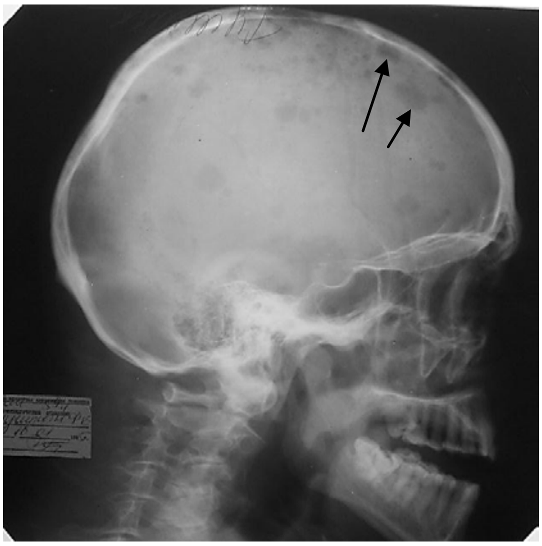


Fig. 5.70. The survey radiograph of the skull in a lateral projection. Multiple sites of destruction of various sizes and round form with distict contours in bones of the skull (arrows) are defined. Multiple (plasma cell) myeloma is detected

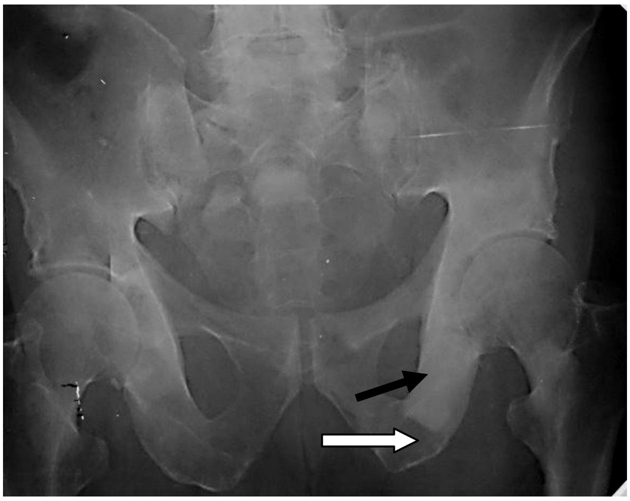


Fig.5.71. The survey radiograph of the pelvis in a direct projection. Multiple sites of osteosclerosis and destruction in pelvic bones are detected. Separate sites of osteosclerosis and destruction are designated by an black arrow and a white arrow, accordingly. Osteolitic and osteoblastic cancer metastases in the iliac bone is detected

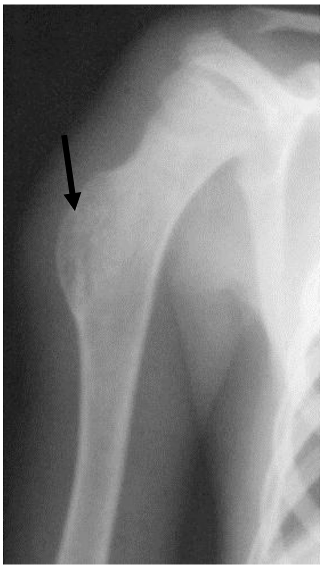


Fig. 5.72. The radiograph of the humeral bone in a direct projection. The mass in the top third of diaphysis of the humeral bone with wide basis connected with the bone is detected (arrow). There are no periosteal reactions, contours are distinct. Radiological symptoms of osteoma are detected (a benign tumour of a bone)

Benign tumours can contain calcification centers (chondroma, osteochondroma) (fig. 5.73, 5.74).

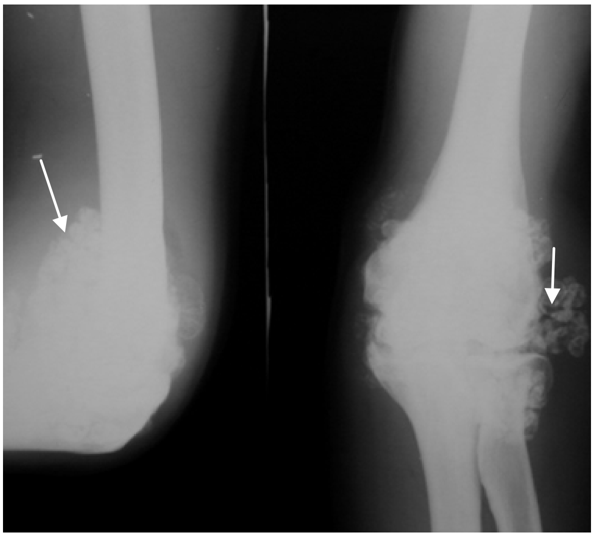


Fig. 5.73. The radiograph of the ulnar joint in direct and lateral projections. The pathological mass, which surrounds the ulnar joint (arrows) is detected. There are lucent sites and zones of calcifications with various sizes and forms; contours are distinct, but not along the whole length. Ecchondroma of ulnar joint bones

Fig. 5.74. 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 metaphysic is detected

Can be absolutely unstructured defect (fig. 5.75).

Fig. 5.75. 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 cystis detected

Slow growth of tumor is characteristic in view of the general good condition of patient. 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) sequesters, 2) single layer periosteal reaction, 3) transition to a joint are often 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 joints diseases

The most often diseases of joints are degenerate 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 or osteophytosis); 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 in the articulate ends of bones. In contrast to the destructive centers, they have correct form, distinct smooth contours and do not contain sequesters (fig. 5.76).

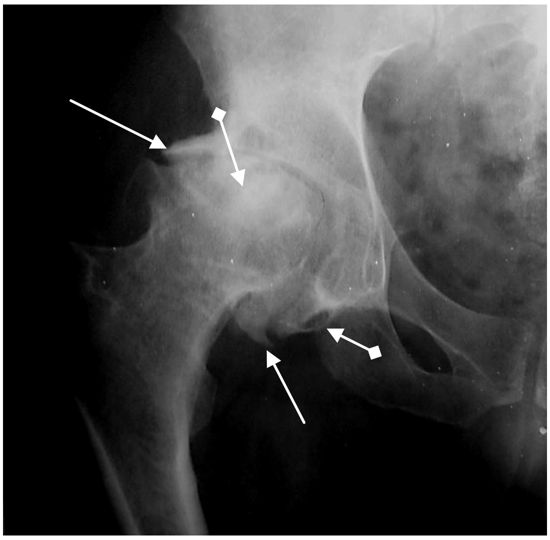


Fig 5.76. Radiograph of the right hip joint in a direct projection. Narrowing and deformation of joint, osteophytes (arrows), subchondral sclerosis, cysts are detected in both femoral head and acetabulum (arrows with rhombus) is indicated. Osteoarthrosis of the hip joint is detected

In ultrasonic scanning regional osteophytes and even degenerative subchondral cysts are detected, as well as defects of the articulate cartilage, especially in large 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.