Weis V.[1,2,] Lehotská V.[2]

[1] Clinic of Radiology and Imaging Methods Trieda SNP 1, 040 11 Košice
[2] II. Radiological Clinic LFUK and OÚSA, Heydukova 10, 812 50 Bratislava

Bone imaging using ultrasound

The main position of the work:
Diagnosis of malignant bone tumors in adults using usg

Abstract
Bone imaging using ultrasound can be included in the imaging algorithm of bone tumors. The National Oncology Register records an increase in malignant diseases since 1930. Malignant tumors are the most common cause of death in developed countries after cardiovaskular diseases. The incidence of malignant bone tumors is less than 1% per 100,000 inhabitants, while primary tumors in adults account for approximately only 0.2% (1). The most common localization causing malignant tumors are bones. Up to 70% can be found in the bone of a primary breast tumor, in 30-40% of lung or kidney tumors (2). In our article, we first described how ultrasound waves are produced, how an image is obtained, how the examination itself takes place and what are the advantages and disadvantages of ultrasonography. In the next step, the author describes the imaging of tumors and bone metastases and explains in more detail the use of ultrasonography in the differential diagnosis algorithm. Subsequently, the author deals with the most common primary bone tumors and bone metastases. In the last step, the author analyzes case from our workplace with photo documentation.
Key words: ultrasonography, bone tumors, bone metastazes

Introduction

The diagnosis of bone diseases is primarily based on their imaging using X-ray, CT, MR or PET/CT, depending on the location and clinical manifestation. Ultrasonic mechanical waves do not pass through the periosteum. Due to the different acoustic impedance, the ultrasound examination is suitable for imaging the bone surface. Ultrasound examination is mainly used as an additional examination of soft parts in the differential diagnosis of swelling (3).

Ultrasonography

Ultrasonography is an imaging modality that uses ultrasound waves at a high frequency inaudible to the human ear to image intra – abdominal organs, blood vessels, lymph nodes, thyroid gland, soft tissues and other tissues amenable to sonography. We know several ultrasound images such as A mode, B mode, mode, D mode, intravascular, transesophageal, intracavitary, 3D, 4D ultrasound or elastography. We can also use ultrasound for USG guided biopsy. The principle of the creation of ultrasonic waves is based on a transducer located in the probe that converts the electric current into ultrasonic waves, which are then transmitted to the examined area using the probe. Ultrasonic waves propagate throught space as a wave of alternating thickening and thining of molecules. Each organ or tissue has a different acoustic impedance. Depending on the different acoustic impedance of the tissue at their interface, part of the ultrasound waves is reflected and part passes through the tissue to the next tissue interface. The reflected ultrasonic waves are captured by the probe, which the transducer converts back into an electric current. The computer converts the pattern of electrical signals into an image that we see on the monitor as a digital computer image. The biggest advantage of ultrasound is that it does not use ionizing radiation but mechanical sound waves. Other advantages are availability and price. The disadvantage of ultrasound is that it does not pass through gas and bone, sometimes the problem is an uncooperative patient or the experience of the examiner. The examined area must be exposed and a gel applied to part of it for better conductivity. Patients are required to fast and have a full urinary bladder before the examination. An ultrasound examinations is a dynamic examination where we can observe the movement of parts, organs or structures in real time, for example the heartbeat of the fetus (4, 5).

Classification of bone diseases

Acquired bone diseases can be divided into acute and chronic, respectively traumatic and non-traumatic. We include contusion, fissure and bone fracture as traumatic. Non-traumatic include inflammatory, metabolic, degenerative diseases and cancer.

Bone imaging using ultrasonography

In common practice, bone pathology is investigated using the x-ray modality due to its high sensitivity and specificity. Ultrasound is mainly used as an additional examination of adjacent soft tissues in bone damage, in first-line management. CT and MR have a higher sensitivity and specificity than an ultrasound examination, therefore these higher imaging modalities are used for a more accurate diagnosis. The exact diagnosis is determined only by histology of the damaged part. Due to the different acoustic impedance of bone and soft tissues, we can visualize the surface of the bone with the help of USG examination. In the USG image, we can observe a hyperechoic cortical line, which is covered by the periosteum, while USG waves are reflected from the periosteum. Tendons and ligaments are not covered by periosteum, so they are permeable for USG examination. The periosteum is heavily blood-stained and provides bone nutrition. We can therefore observe irregularities on the periosteum, which represent nutritional canals. The advantage of USG is the absence of ionizing radiation, price, examination speed and availability. The experience of the examining doctor can be a limitation.

Cancerous bone diseases

Bone tumors are divided into primary and secondary. The incidence of primary bone tumors is less than 1% per 100,000 inhabitants (1). Each type of primary tumor has its own predilection location, age and gender, which is used in differential diagnosis. Enneking‘s scheme is used for the staging of bone tumors, where two aspects of the tumor are evaluated, namely the degree of differentiation and anatomical localization (6). Grading is determined based on the ratio of differentiated and undifferentiated tumor cells in the histological image, which we call the Broders system. When determining the localization, the invasion of the tumor into the surrounding soft parts is taken into account (7).

Plasmacytoma

The most common primary malignant bone tumors include plasmacytoma or multiple myeloma, if there are more bone lesions. It is a hematopoietic tumor arising from the plasma cells of the marrow, causing lytic destruction of the skeleton. In the given lytic terrain, pathological fractures may subsequently occur. The clinical manifestation consists of symptoms known by the abbreviation CRAB. Hypercalcemia represents an increased level of calcium in the blood as a result of the excessive destruction of bone tissue, which we observe as bone lytic lesions. Another symptom may be renal failure due to overproduction of paraprotein and blockage of the renal tubules. Anemia associated with it, fatigue and dyspnea are other symptoms of this disease. Another complication can be infections or a hyperviscous condition. Diagnosis is based on the imaging of bone lesions using X-ray, CT or MR imaging and a laboratory profile (8).

Osteosarcoma

The second most common bone tumor is osteosarcoma. Characteristic for this tumor is the speed of growth, destruction of bone and speed of metastasis. The predilection site of osteosarcoma is the metaphysis of long bones, which is affected in up to 80%. According to Picci (9), micrometastases are present at the time of diagnosis. The most common occurrence of osteosarcoma is in young adolescents, where the osteoblastic type of tumor is most often observed, and in older patients over 40 years of age, where the osteoclastic type of tumor is observed (10). Patients with this type of tumor survive for a short time. The clinical manifestation consists of pain in the affected bone, swelling, limited mobility or a pathological fracture even with a light load. Diagnostics is based on imaging methods - x-ray, ct, mr, pet/ct or scintigraphy. On the images shown, we can observe the tumor itself, its growth into the surrounding area, or Codman‘s triangle during the periosteal reaction. Due to the rapid growth of the tumor, the periosteum reacts with a malignant spicular periosteal reaction, which can also be observed on ultrasound. The final diagnosis is determined by the histological image (11).

Bone metastases

Metastases of various tumors most often occur in bone tissue. For prostate and breast cancer, it is at least 70%. Lungs and kidneys metastasize to bones in up to 30-40% of cases, according to studies that were done post mortem. The axial skeleton is the most frequent localization of mts due to its significant blood supply and extracellular matrix. The clinical manifestation of bone metastases is manifested mainly by pain in the affected bone and also by symptoms of oppression or growth into the surrounding parts. In a more advanced stage, we can observe a pathological fracture in the lytic terrain of the mts. In the management of the differential diagnosis of mts of bones, the same procedure applies as in the diagnosis of primary bone tumors. The most sensitive imaging examination of the axial skeleton is MR, but due to its speed, cost and availability, it is not used as a screening examination. We consider pet/ct to be the basic imaging modality for mts involvement of any tumor of all organ systems, including bones, where we can also determine its metabolic activity. In some cases, using imaging methods, we can also find an incidentaloma, i.e. a random mts of bone, whether of unknown or known origin, similar to our patient (12)

Case study

A polymorbid 77-year-old patient was referred to the ultrasound clinic for the purpose of differential diagnosis of swelling of the left thigh. The patient arrived accompanied by lower medical staff on a wheelchair, while she moved from the wheelchair to the USG examination table by herself. Subjectively, the patient felt slight pain in the area of the left thigh. The patient is an ex-nicotine with a known primary lung tumor. Before the USG examination, the surgeon made a working diagnosis of deep vein thrombosis in a paraneoplastic process. In the USG examination of the left lower limb, both deep and superficial venous thrombosis were ruled out. In the front part of the thigh, the USG image showed edematous infiltration and thickening of the muscle layers of the thigh and adjacent soft tissue structures. When the probe pressed on the edematous structures, the patient reacted significantly with pain. The cortex of the femur in the upper 1/3 was smooth without any pathological process. The cortex was pathologically altered in the middle and lower 1/3 of the femur. In the USG image, a spicular periosteal reaction with pathological irregular blood flow was observed in the CFM image. At the end of the USG examination, a local malignant disease of the femur diaphysis bone was assumed. Due to the above-mentioned fact that USG mechanical waves do not pass through bone tissue, the patient was recommended for X-ray and CT examination as part of the differential diagnosis. In the x-ray image, a pathological fracture in the lytic terrain of the bone with a spicular periosteal reaction was described in the middle 1/3 of the femur diaphysis. During the CT examination, pathological growth of the suspicious mts process of the bone into the surrounding soft tissue structures was described as a novelty. Considering the general clinical condition of the patient and the known primary lung tumor, biopsy and subsequent histology is not necessary.

Conclusion

Metastatic bone involvement is an incurable disease, in which we try to improve the patient‘s quality of life and relieve pain. In the case of cancer, early diagnosis can help detect cancer in an early treatable stage without distant mts. Therefore, regular preventive examinations and screening programs are essential. Diagnosis of cancer and mts is based on clinical examination, laboratory tests and imaging. In some cases, radiologists manage to detect a random tumor or mts of organs and organ systems using various imaging methods.

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List of abbreviations

UNLP – Louis Pasteur University Hospital
X-ray – X-ray
CT – computer tomography
MR – magnetic resonance
PET/CT – positron emission tomography/ computed tomography
CRAB – symptom abbreviation – hypercalcemia, renal failure, anemia, bone lesions
CFM – color flow mode – Doppler ultrasound examination for the presence of blood flow

Corresponding author:
MUDr. Viliam Weis, L. Pasteur University Hospital,
Trieda SNP 1 040 11 Košice
Email: dr.weisviliam@gmail.com
The autor agrees to the publication of the data

Image documentation

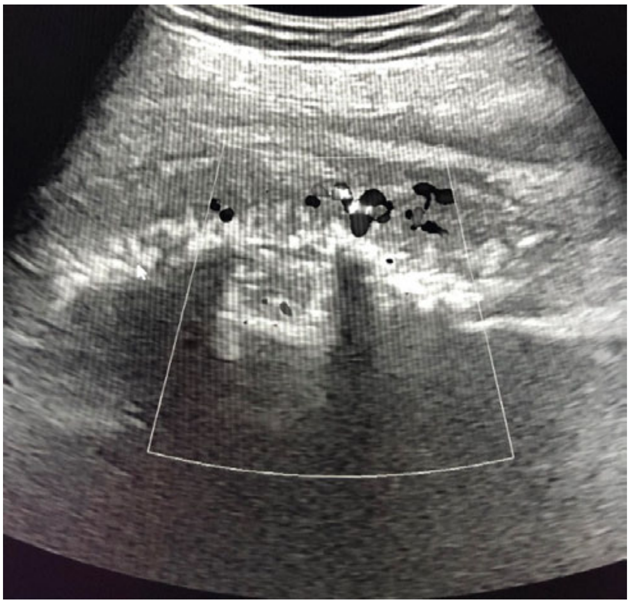

Image 1 – ultrasound of the femur - spicular periosteal reaction with irregular blood flow in the CFM image – mts of the bone

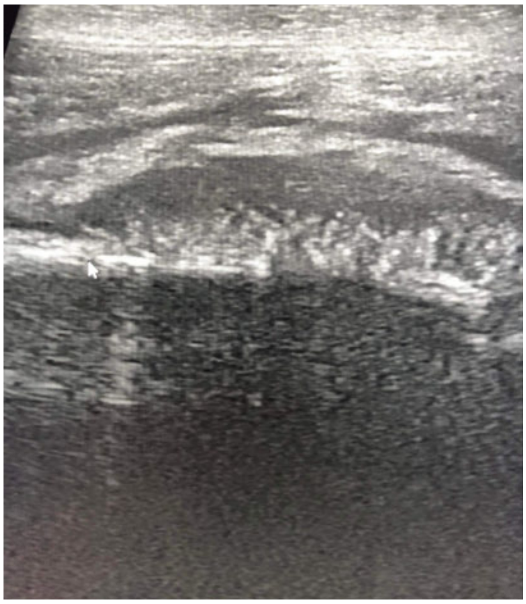

Image 2 – ultrasound of the femur - spicular periosteal reaction, the mouse cursor represents the breaking point of the break between the damaged and undamaged part of the cortex. Invasion of mts into the surrounding soft tissues of the thigh

Image 3 – ultrasound of the femur, transverse projection, interface of the middle and lower 1/3 of the femur, spicular periosteal reaction

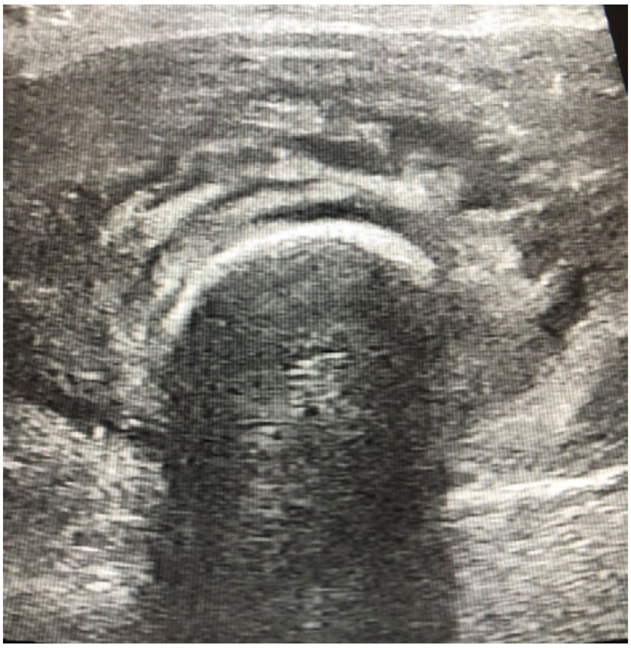

Image 4 – ultrasound of the femur, transverse projection, upper 1/3 of the femur, without pathological involvement of the cortex

Image 5 – x-ray of the femur - pathological fracture in the lytic terrain of the mts, spicular periosteal reaction

Image 6 – CT of the femur, soft tissue window, pathological fracture of the femur in the lytic terrain of the mts bone with invasion into the surrounding soft tissues

Image 7 – VRT reconstruction, CT of the femur, pathological fracture of the femur