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METHODS OF INVESTIGATION IN BONE DESTRUCTION: MODERN APPROACHES

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Abstract. This article reviews the main diagnostic methods used to visualize bone destruction processes - radiography, computed tomography (CT), magnetic resonance imaging (MRI), radionuclide scintigraphy, and positron emission tomography (PET). The advantages and limitations of each method are highlighted, especially their role in the early detection of bone destruction in the setting of oncological diseases. Абстрактный.В данной статье рассматриваются основные методы диагностики, используемые для визуализации процессов деструкции кости - рентгенография, компьютерная томография (КТ), магнитно-резонансная томография (МРТ), радионуклидная сцинтиграфия и позитронно-эмиссионная томография (ПЭТ). Описаны преимущества и ограничения каждого метода, особенно их роль в раннем выявлении костной деструкции при онкологических заболеваниях.

Key word: bone destruction, visualization, CT, MRI, PET, scintigraphy, metastasis.

МЕТОДЫ ИССЛЕДОВАНИЯ ПРИ РАЗРУШЕНИИ КОСТЕЙ: СОВРЕМЕННЫЕ ПОДХОДЫ

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Аннотация. В данной статье рассматриваются основные методы диагностики, используемые для визуализации процессов деструкции кости - рентгенография, компьютерная томография (КТ), магнитно-резонансная томография (МРТ), радионуклидная сцинтиграфия и позитронно-эмиссионная томография (ПЭТ). Описаны преимущества и ограничения каждого метода, особенно их роль в раннем выявлении костной деструкции при онкологических заболеваниях. Abstract.This article discusses the main diagnostic methods used to visualize bone destruction processes - radiography, computed tomography (CT), magnetic resonance imaging (MRI), radionuclide scintigraphy and positron emission tomography (PET). The advantages and limitations of each method are described, especially their role in the early detection of bone destruction in oncological diseases.

Ключевые слова: костная деструкция, визуализация, КТ, МРТ, ПЭТ, сцинтиграфия, метастазы.

Intraduction. Bone destruction is a complex pathological condition characterized by the destruction, erosion or resorption of bone tissue, which develops against the background of oncological, infectious, inflammatory and metabolic diseases. Especially in tumors that have metastasized to the bone, destructive processes are common and are accompanied by pain syndrome, decreased quality of life and the risk of bone fractures. Therefore, early detection and assessment of bone destruction is an important task of modern diagnostic systems.An example is stereomicroscopy based on histological sections, that provides the possibility to assess bone damage and remodeling at a resolution higher than 2 μm, or scanning electron microscopy. However, these techniques are destructive and, in the case of stereomicroscopy, are restricted to a bidimensional analysis. The three-dimensional evaluation of bone damage at a higher resolution is crucial not only from a research perspective, but especially from the clinical point of view; the comprehension of the micro-damage physical principle and its visualization is a relevant opportunity to understand changes in the diseased tissue and to provide insights into the prevention of age-related fractures. This could be performed by the implementation of micro- and nano-scale fragility indexes, obtained with the aid of numerical models that use, as a source, micro-scale images of bone. In this context, a wide interest is devoted to micro-CT scans and synchrotron radiation (SR) images. They provide, in fact, a three-dimensional reconstruction of bone micro-architecture, which is important for the identification of microdamage, offering the optimal balance between resolution and field of view. In addition to this, the SR technique is a promising solution for the real-time visualization of bone damage, allowing the performance of mechanical tests inside the synchrotron facility. The disruptive advent of these high-resolution in vitro techniques offers the possibility to experimentally validate numerical damage models, as deeply discussed in the section “Validation approaches to multiscale damage models”. Additionally, these techniques could help the study of effective pharmacological treatments for bone pathologies.

Materials and metods: This review article summarizes the diagnostic capabilities of various imaging modalities based on the medical literature and clinical experience. The sensitivity, specificity, and clinical applicability of each modality were evaluated.

Results and discussion. Radiography Radiography is the initial and most cost-effective method for detecting bone destruction. However, destructive changes are detected on radiographs only after at least 30% of bone mass has been lost. 2. Computed tomography (CT) CT provides high-resolution images of the cortical and trabecular structures of the bone. It is of great clinical importance in detecting subtle destruction, especially in the spine, skull, and shoulder regions. Magnetic resonance imaging (MRI) MRI is one of the most effective methods for assessing bone marrow, tumor infiltration, and soft tissue invasion. Radionuclide scintigraphy Bone scintigraphy (usually using 99mTc-pyrophosphate) detects changes in bone metabolism at an early stage. Positron emission tomography (PET/CT) PET/CT, especially with the isotopes 18F-FDG or 18F-NaF, assesses the metabolic activity of tumor cells.

Conclusion. A comprehensive approach is required to identify bone destruction. Each diagnostic method has its own advantages and limitations. Although radiography is used for initial assessment in clinical settings, CT, MRI, and radionuclide methods are important for in-depth and accurate diagnosis. PET/CT, on the other hand, has high sensitivity in modern oncological practice and is an important tool in formulating a treatment strategy. Micro-scale models provide further insights into bone fracture prediction at smaller scales. Traditionally, micro-architectural features were assessed by means of histological sections.that lack in three-dimensionality. Nowadays, the input of micro-scale models often comes from micro-CT or SR images, that have a resolution able to non-destructively capture not only trabecular architecture, but even ultrastructural porosities, such as lacunae. However, this corresponds to higher computational costs, calculated by van Rietbergen et al. through an element-by-element method that implies the use of uniformly shaped elements to reduce memory allocation and optimize computational times. Some issues arise when dealing with micro-CT or SR imaging techniques: filtration and segmentation. Reconstructed image data include noise that should be removed or at least reduced by filtering. The choice of an adequate filter (the Gaussian filter is the most suitable one, which is easily implementable and fast in computation is essential in order to obtain an input image for the model, as close as possible to the original sample. Another relevant aspect is the correct segmentation process that selects those voxels that are below or above a defined threshold, so as to separate those elements that are bone and those that can be considered as voids.

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