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METHODS OF DIAGNOSIS OF ACUTE EPIPHYSEAL OSTEOMYELITIS IN CHILDREN

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Summary. The article presents the analysis of different method for diagnosis of epiphyseal osteomyelitis, including radiography, ultrasonography, computed tomography, magnetic resonance tomography, and radioisotope bone scans. We address the advantages, disadvantages, and possibilities of each method from the standpoint of early diagnosis of osteomyelitis in children.
Based upon the literature, the most effective and reliable methods for early diagnosis of epiphyseal osteomyelitis in pediatric patients are magnetic resonance and ultrasound. The present diagnostic methods involve no radiation exposure. Using an ultrasonic diagnostic method does not require complete immobility of the patient, can be used from the moment of birth, has widespread availability, and has a relative low cost to allow its use in any medical institution.

Keywords: acute epiphyseal osteomyelitis, child, radiography, ultrasound diagnostics, computed tomography, magnetic resonance imaging, radionuclide bone scan.

МЕТОДЫ ДИАГНОСТИКИ ОСТРОГО ЭПИФИЗАРНОГО ОСТЕОМИЕЛИТА У ДЕТЕЙ

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В статье представлен анализ различных методов диагностики эпифизарного остеомиелита — рентгенография, ультразвуковая диагностика, компьютерная томография, магнитно-резонансная томография, радиоизотопная остеосцинтиграфия. Приводятся недостатки и преимущества, а также оцениваются возможности каждого из методов с позиций ранней диагностики остеомиелита у детей.
По данным литературы, наиболее эффективными и надежными методами ранней диагностики эпифизарного остеомиелита в педиатрической практике являются магнитно-резонансный и ультразвуковой, у представленных методов отсутствует лучевая нагрузка, в то же время при использовании ультразвукового метода не требуется полная неподвижность пациента, его можно применять с момента новорожденности и в любом количественном режиме, а общедоступность и относительная низкая стоимость ультразвуковой аппаратуры позволяет иметь ее в любых медицинских учреждениях.

Ключевые слова: острый эпифизарный остеомиелит, ребенок, рентгенография, ультразвуковая диагностика, компьютерная томография, магнитно-резонансная томография, радиоизотопная остеосцинтиграфия.

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Acute epiphyseal hematogenous osteomyelitis occurs in children at an early age and is accompanied by frequent disability due to development of various severe orthopedic pathologies. Orthopedic complications (dislocations, deformities, limb shortening, contractures, and ankyloses of large joints) are observed in 31%–71% of cases [1-5], and early diagnosis and timely treatment can reduce the number of complications and contribute to complete recovery in 95% of cases [6]. In this article, we review the literature on the techniques and methods used to diagnose epiphyseal osteomyelitis and discuss the most promising ones that can provide qualitative, early, and affordable diagnosis as well as reduce the number of unsatisfactory outcomes.

The anatomical features of bone structure and blood circulation in children of different ages lead to different localizations of purulent foci of lesions in various parts of the bone. The autonomy of blood circulation in each part of the bone and the more developed network in the epiphysis explains the prevalence of epiphyseal osteomyelitis in younger children. Depending on the age and development of the epimetaphyseal bone, the osteomyelitis process may be localized in the cartilaginous tissue of the epiphysis, the focus of ossification, or the meta-epiphyseal zone [7, 8]. In older children, blood circulation in different parts of the bone becomes unified, with a more developed network of metaphyseal vessels, which explains the predominant localization of purulent foci in the latter [6-8].

Currently, early diagnostics presents significant difficulties because the pathomorphosis of the disease produces subclinical forms of inflammation [9]. The traditional technique used to diagnose epiphyseal osteomyelitis in children is radiography [10], which enables evaluation of the shape, contours, structure, and relationship between the bones. Within 24–48 hours from the appearance of clinical signs, it is possible to determine the increase in the volume of tissues and abnormalities in the sharpness of the muscle contours and paraosseous soft tissues, but these signs are not reliable and are rarely detected [6, 11]. Additionally, in the early stages of the osteomyelitic process, it is possible to identify the signs of regional osteoporosis and disorders in the trabecula structure of bone [12-14]. In later periods of the disease (starting from the 14th day), a periosteal reaction can be detected on radiographs, which manifests itself in the form of hypertrophy and thickening of the periosteum, extensive foci of destruction appear as well as linear and layered periosteal stratifications, and sclerosis sites around the destruction zones [15-19]. On the other hand, in young children, when the process is localized in the epimetaphyseal zone, the periosteal reaction is weak or not defined at all [20]. According to recommendations of the American Society of Infectious Diseases [21], if there are no clear signs of osteomyelitis on the first radiograph, it is necessary to acquire a second one ≥2-4 weeks because the radiological signs appear on average 2-4 weeks after the clinical manifestations, and the changes in the bone tissue can be visualized on 90% of the radiographs only by day 28 of the disease [22]. The accuracy of radiography in the early diagnosis of osteomyelitis is not >50%-60% [23]. The sensitivity of the method ranges from 43%-75%, and the specificity is 50% [13, 24]. In addition to late diagnosis, the drawbacks of this method are the high-radiation dose, low specificity, and low resolving power [16].

Computed tomography (CT) can increase the informative value of X-ray diagnostics of acute epiphyseal osteomyelitis in children and enables visualization of less pronounced changes than is possible by using conventional radiography [15, 16]. CT can provide a clear image of a cortical layer to assess the condition of surrounding soft tissues, determine the presence of foci of destruction and periosteal reaction, and visualize the osteolysis of the cortical layer and trabeculae of bone in detail [11, 25]. CT is used to determine the signs of epiphyseal osteomyelitis of bones in composite joints and can for emergency diagnostics of osteomyelitis [26]. The sensitivity of CT in the diagnosis of osteomyelitis is 67%, and the specificity ranges from 75%-83% [15]. The drawback of this method is the significant radiation dose and need for general anesthesia in young children.

In the early stages of the disease, bone scans are sometimes performed in diagnostically complicated cases [15]. Scintigraphy with technetium-99 m can be used to confirm the diagnosis within 24-48 hours from the beginning of the development of the infectious process in 90%–95% of patients [27]. When performing scintigraphy with gallium-67, the radiopharmaceutical agent is accumulated in places with leukocytes and bacteria accumulation. Gallium can accumulate in patients with acute epiphyseal osteomyelitis in those foci in which there is a normal or decreased accumulation of masurium ("cold foci") [13]; however, when using this technique, a large number of false-negative and false-positive results are obtained [15]. Additionally, the disadvantages of radionuclide studies are their high cost and the long time required for full processing of the examination results (in some cases, more than a day).

If there is a suspicion of acute hematogenous osteomyelitis in early childhood, magnetic resonance imaging (MRI) can be performed rather than scintigraphy [28]. With MRI, inflammatory changes in the bone marrow and soft tissue structures that develop within 1–5 days after disease onset can be diagnosed. MRI enables assessment of the area of the pathological process propagation by visualizing a clear boundary between the edge of the bone and zone of soft tissue edema [15]. Damage to joints also can be assessed by MRI. For diagnosing the condition of the soft tissue surrounding the bone and bone marrow, MRI is a more accurate method than CT. The periosteal reaction is often not visualized on MRI, but if it is, it will be before the stage of ossification, so it will be visible earlier on MRI than on CT [19]. If a more detailed study is needed, contrast agents containing iron nanoparticles having superparamagnetic properties can be used. After introduction into the body, these particles are captured by the cells of the reticuloendothelial system and accumulate in macrophages and fibroblasts in the inflammatory focus. These contrast agents can help to visualize more clearly the area of inflammation [29, 30]. The use of contrast agents with gadolinium enables better visualization of the changes in the bone marrow as well as disorders of the blood supply of the bone. Gadolinium accumulates in the hypovascular regions of the bone, which enables differentiation of osteomyelitis from phlegmon of soft tissues or abscess.

Studies with contrast agents enable diagnosis of epiphyseal osteomyelitis with greater confidence if there are signs of periosteal edema or edema of soft tissues on the MR tomogram [31].

A.M. Davies described fat particles in the focus of inflammation that were associated with either bone marrow edema or with the presence of linear or spherical particles of necrotic bone marrow [32]. Visualization of adipose tissue is reasonable because in an acute process, bone marrow necrosis occurs and the free fat particles release and form complexes with pus, which can be detected. Penetration of fat into soft tissues through Leeuwenhoek canals is considered an indirect sign of disruption of the integrity of the bone cortical layer [33].

MRI is the preferred imaging technique because of its high sensitivity (82%-100%) and specificity (75%-99%) in contrast to the limited applicability of CT and ultrasound [9, 13, 34]. If the short tau inversion recovery sequence is used, MRI is 100% predictive of a negative result, and the diagnosis of osteomyelitis can be ruled out if there are no changes in MR tomograms [13]. The disadvantages of MRI are the expensive equipment, which is not always available, high cost of the procedure, artifacts in the presence of metal implants, and need for general anesthesia to prevent movements of very young children during the study.

Among modern medical technologies, ultrasound diagnostics are increasingly used. A peculiarity of ultrasound examination of the osteoarticular system in children is the penetrating ability of ultrasound, which is greater than in adults and is associated with the mineral composition of bone tissue and low density because of the incomplete process of osteogenesis when the epiphyzes of bones consist mainly of cartilaginous tissue. These features of the skeleton structure enable determination of the degree of development of the foci of ossification as well as pathological changes in the cartilaginous epiphyses and adjacent parts of the bones [4, 6, 14-16]. The changes in bone tissue and surrounding soft tissues become apparent in the early stages of the disease [35]. Changes in soft tissues in epiphyseal osteomyelitis occur with respect to thickening, echogenicity (often increased), presence of fluid accumulations located para-articularly, and enhancement of venous vascular pattern [12, 36]. Changes in adjacent joints involve enlargement of the joint cavity with a heterogeneous fine effusion and thickening of the capsule with proliferation of the synovial membrane. The expansion of the cavity and change in the capsule are manifested to a greater extent when the large (hip and knee) joints are affected. The heterogeneous character of the effusion is noted in the first week of the disease, with subsequent transition to a homogeneous anechoic effusion, which is associated with sanitation of the purulent cavity during the treatment. The reaction of the synovial membrane depends on the duration of the disease; the synovial membrane becomes thicker and more echogenic the longer the child is sick [37]. Increases in the thickness of the capsule and its echogenicity without joint effusion are possible [36]. Ultrasound examination of the epiphyseal sections of bones shows the heterogeneity of the epiphyseal cartilage in the form of local areas of increased echogenicity [36].

In infants, the changes in the cartilaginous epiphysis are manifested in the form of anechoic inclusions of 2–3 mm. When studying the focus of ossification of the epiphyseal bone, a change in its shape and structure is observed. In this case, the unevenness of its outer contour, deformity represented by an irregular shape of the hyperechoic structure or in the form of the annular shape of the hyperechoic structure with the presence of an anechoic region in the center is possible. The focus of ossification can be fragmented [36]. Echography can be used to determine the fluid in the joint cavity with a volume of 0.3–0.5 ml and the nature of the effusion as well as to assess the condition and position of the epiphysis, which enables detection of pathological dislocation present during the acute period [38].

Thus, with the help of ultrasound, the following signs of epiphyseal osteomyelitis can be detected: the heteroehogenicity of the hyaline epiphyseal cartilage, including anechoic inclusions; deformities; fragmentation; annular shape; foci of ossification; deformity and heterogeneity of the metaepiphyseal zone with the presence of anechoic inclusions in the epiphysis; and changes in the periosteum and bone cortical layer [36]. Ultrasound enables diagnosis of acute epiphyseal osteomyelitis in the first 2–3 days of the disease. In this case, the sensitivity of echography for diagnosis of epiphyseal osteomyelitis is 90% and the specificity is 100% [12].

Conclusion

To date, the problems in the diagnosis epiphyseal osteomyelitis in children at early stages of development have not been definitively resolved. Ultrasound is the preferred technique for diagnosis of very early stage (days) acute epiphyseal osteomyelitis.

1. Ultrasound enables early detection of edema and infiltrative changes in muscles and soft tissues as well as accumulation of fluid in the joint. The method is safe, informative, and can be performed frequently.

2. MRI is highly informative in the first 10-14 days but requires special equipment and anesthetic support.

3. Radiography remains the simplest and most affordable technique at late stages of acute osteomyelitis (2 weeks after disease onset). Bone changes are more clearly defined by CT, but, as with radiography, more than a week must pass before the changes can be visualized, and the high radiation dose must be considered.

4. Radionuclide research is successfully used both for diagnosis of acute epiphyseal osteomyelitis and for evaluating the efficiency of the therapy in the postoperative period, but because of age limitations, this approach cannot be used in young children.

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