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Descriptive review

Brief Overview of Modern Methods of Radiological Diagnostics of Osteomyelitis

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Abstract

Osteomyelitis is inflammation of the bone that is usually due to infection. An inadequate or late diagnosis increases the degree of complications and morbidity; for these reasons, imaging techniques are essential to confirm the presumed clinical diagnosis and to provide information regarding the exact site and extent of the infection process.

This review discusses various imaging tools employed to diagnose osteomyelitis: X-ray, computed tomography, magnetic resonance imaging, ultrasound, bone scintigraphy, and positron emission tomography.

When used appropriately, diagnostic imaging can provide high sensitivity and specificity for detecting osteomyelitis, making radiological evaluation a crucial step in the diagnostic process of this debilitating condition.

Keywords: osteomyelitis, X-ray, computed tomography, magnetic resonance imaging, bone scintigraphy, positron emission tomography, ultrasound.

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Introduction

Osteomyelitis is a non-specific infection of bone and bone marrow. In the past acute osteomyelitis (AO) led to high mortality especially in non-adults [1].

Despite this, it has to this day proved impossible to identify definite criteria that would allow a reliable diagnosis. It is therefore very difficult to compare different investigation and treatment methods, and evidence-based results are few. The reason for this is the most important characteristic of the disease: the extreme variety of symptoms that can be manifested in chronic osteomyelitis. This variety makes a systematic description difficult; even experienced clinicians are repeatedly taken by surprise by new and unpredictable courses of the disease [2-5]. Imaging plays a vital role in the diagnosis of osteomyelitis.

This review describes the role of common imaging modalities utilized in clinical practice based on current literature.

Literature Search Strategy

NCBI's PubMed database was utilized to search for literature pertaining to the diagnostic imaging of osteomyelitis. Combinations of the following search terms were used: bone infection, osteomyelitis, diagnosis, radiology, diagnostic imaging, imaging, magnetic resonance imaging, MRI, computed tomography, CT, x-ray, plain film, radiograph, bone scan, bone scintigraphy, positron emission tomography, PET, ultrasound. Primary and secondary sources were screened for relevance by title and the contents of the abstract. Potential sources were then downloaded and their contents were scrutinized for relevance. The authors also incorporated guidelines from the Infectious Diseases Society of America (IDSA). A total of 23 references were included in the final review.

X-rays (Plain Films)

In many patients, X-rays are the first diagnostic tool utilized in the radiographic work-up of osteomyelitis. X-rays are widely available and inexpensive; however, they are limited in their ability to detect osteolytic changes. Early radiographic findings may include: soft tissue or deep soft tissue swelling, muscle swelling, or blurred soft tissue planes [6]. Early bone findings may include: periosteal thickening, lytic lesions, endosteal scalloping, osteopenia, loss of trabecular architecture, and new bone apposition. Pineda et al. reports that osteomyelitis must extend at least 1 cm and compromise 30 to 50% of bone mineral content to produce visible changes in plain radiographs [7]. Pineda reports the sensitivity and specificity of plain films to be 43 – 75% and 75 – 83% respectively. A major limitation is that these findings may not be present for 10-21 days after the onset of an infection. As such, X-rays may be more useful for patients who have had a delay in seeking care and did not present until greater than three weeks after symptom onset. A strength of X-rays is the ability to detect alternative diagnoses such as metastatic lesions or osteoporotic fractures. Despite their limitations, X-rays should routinely be utilized in patients with suspected osteomyelitis [8,9]. They provide an inexpensive tool to evaluate for alternative pathology while their sensitivity improves with time from initial presentation. However, if the diagnosis remains unclear after X-rays and laboratory testing, further imaging should be obtained.

Magnetic Resonance Imaging

MRI provides excellent delineation between bone and soft tissue as well as abnormal and normal bone marrow. Furthermore, it can detect osteomyelitis as early as 3–5 days after infection. MRI is used to evaluate the extent of abnormalities and in cases of surgical treatment, it is valuable for planning an accurate surgical strategy or clinical follow-up [10-12].

Magnetic resonance imaging (MRI) is a vital tool for the initial diagnosis of acute osteomyelitis. MRI has the ability to detect changes in bone marrow within three to five days of infection, offering a distinct advantage over x-rays. MRI also has the ability to detect necrotic bone, sinus tracts, and abscesses, and it can be used to formulate preoperative plans and guide surgical debridement. Sinus tracts, fistulas, and abscess visualization can be further enhanced by the use of gadolinium contrast. However, gadolinium based contrast has been linked to nephrogenic systemic fibrosis and should be used with extreme caution or avoided altogether in patients with moderate to severe renal impairment. In a meta-analysis of 16 studies, MRI was found to be superior to plain films, three phase technetium bone scan, and leukocyte scan for the evaluation of acute osteomyelitis in the setting of diabetic foot ulcers. Another meta-analysis of 5 studies evaluating the use of MRI in chronic osteomyelitis found that the sensitivity and specificity was 84% (95% CI: 69-92) and 60% (95% CI: 38-78) respectively [13]. The specificity of MRI is limited by the fact that bone marrow edema is a non-specific finding that can also be caused by problems such as contusion, fracture, arthritis, or neoplasm. The sensitivity and specificity of MRI also depends on the suspected site of infection. For native vertebral osteomyelitis, MRI has been reported to have a sensitivity and specificity of 97% and 93% respectively, and is therefore the primary imaging modality recommended by the IDSA [14].

Bone Scintigraphy

Bone scintigraphy, commonly referred to as a bone scan, is another imaging option for diagnosing osteomyelitis. Three different scans are routinely employed: three phase bone scan, gallium scintigraphy, and radio-labeled WBC scan. The three phase bone scan utilizes the 99mTc diphosphonate radiopharmaceutical. The first phase involves nuclear angiography, obtaining consecutive two to five second images of the suspected bone during the administration of the radiopharmaceutical. The second phase is obtained within five minutes of administration. Inflammation results in capillary dilation which leads to increased blood flow and pooling. The third phase is obtained approximately three hours later. This phase helps to differentiate between diffuse cellulitis and bone involvement. Osteomyelitis classically results in focal uptake during the third phase whereas cellulitis demonstrates either normal or diffuse uptake resulting from regional hyperemia. These scans have a high sensitivity but are poorly specific; false positives can occur in the setting of recent trauma, prosthetic implants, crystal arthropathy, arthritis, diabetes, or neoplasia.

Gallium scintigraphy utilizes a radiogallium isotope that attaches to the transferrin that leaks from inflamed blood vessels. Inflammation could be due to either infectious or sterile causes. Gallium scans do not show the same level of bony detail as technetium 3-phase scans, limiting their ability to differentiate between bone and soft tissue pathology. Gallium scans are most useful for diagnosing native vertebral osteomyelitis; IDSA guidelines recommend a combined gallium/99m Tc scan for patients who have a contraindication to MRI. This combination has a sensitivity of 91% and a specificity >90% [15]. The third method of bone scanning involves indium-111 labeled leukocytes (99m Tc-hexamethylpropyleneamine oxime in some studies). Similar to a gallium scan, labeled WBC scans provide poor detail of bony structures. Their advantage is having improved specificity compared to the other bone scans; they are especially useful in cases where other conditions are superimposed. Schauwecker et al. reported a sensitivity and specificity of 88% and 85% respectively [16]. Therefore, bone scintigraphy represents a valuable option in the diagnostic imaging of osteomyelitis, and may be especially useful in cases where MRI is unavailable.

Computed Tomography

Computed tomography (CT) has a number of advantages over x-rays; it allows for improved visualization of intramedullary and soft tissue gas, sequestrum, involucrum, sinus tracts, and foreign bodies. CT has superior ability to assess bony architecture and detect necrotic bone (sequestrum) when compared to MRI [17]. The number of cuts in CT is generally greater than those of MRI, reducing the likelihood that pathology may be missed due to small size. This advantage is time dependent, as necrosis may take up to six weeks to develop after the onset of infection. Thus, during the initial stages of the infection, detection of necrotic bone may not be possible. Sequestered bone is strongly suggestive of an infectious etiology. Additionally, CT can detect changes such as soft tissue edema or bone destruction earlier than x-rays. CT can also be used to guide aspiration and needle biopsies. Compared to MRI, the sensitivity and specificity of CT is less impressive. In a meta-analysis, Termaat and colleagues report a sensitivity of 67% (95% CI: 24-94) and a specificity of 50% (95% CI: 3–97) [13]. The drawbacks of computed tomography are the increased cost and radiation exposure compared to plain films; studies may also be limited by the presence of metallic implants or foreign bodies. Nevertheless, CT should be strongly considered in patients who are unable to undergo MRI.

Positron Emission Tomography

Another imaging modality less frequently employed is fludeoxyglucose (18 F) Positron Emission Tomography (PET). The PET scan relies upon the increased expression of glucose transporters in inflammatory cells and measures the uptake of radio-labeled glucose molecules. This technique can produce results within 30 to 60 minutes of tracer administration; it is unaffected by metal implants or foreign bodies, and produces images with higher special resolution than single photon emitting tracers [18,19]. This modality has demonstrated superior sensitivity and specificity to MRI, bone scintigraphy, and leukocyte scintigraphy. A meta-analysis of four studies evealed a pooled sensitivity of 96% (95% CI: 88-99) and a specificity of 91% (95% CI: 81-95) [13]. PET scan has had limited use in clinical practice due to high cost and poor availability; however, in the future it may become more cost effective, as this modality has demonstrated a high level of diagnostic value [20].

Ultrasound

During recent years, ultrasonography has had an expanding role in the investigation of infectious processes of the soft tissues and in early detection of subperiosteal fluid collections that are seen in acute osteomyelitis in childhood [21].

The use of ultrasound as an imaging modality for osteomyelitis is less discussed in the literature. However, it offers a valuable alternative given the widespread access and relatively low cost. Ultrasound can be performed at the bedside and poses minimal risk to the patient. It can also be used to delineate infectious etiologies from tumors or noninfectious causes. Similar to CT and MRI, ultrasound can guide biopsies or aspirations and to assess the extent of soft tissue involvement. Findings such as periosteal elevation, hypoechoic fluid collections around bone, and soft tissue abscesses are suggestive of osteomyelitis. Ultrasound has also been shown to be an exceptional modality for detecting osteomyelitis in sickle-cell patients. It should be noted that ultrasound may be more reliable in children than adults due to a looser adherence of periosteum to cortex in the immature skeleton. A drawback to this modality is a lack of studies looking at its reliability in the diagnosis of adult osteomyelitis, although one study found a false-positive rate of 10.5% [22]. At this time, ultrasound may be best used in combination with other imaging modalities or when other options are unavailable, and prudence should be used in its interpretation.

Conclusion

The authors conclude that plain films are an appropriate first step in imaging for osteomyelitis, as they may reveal osteolytic changes and can help rule out alternative pathology. MRI is often the most appropriate second study, as it is highly sensitive and can detect bone marrow changes within days of an infection. Other studies such as CT, ultrasound, and bone scintigraphy may be useful in patients who cannot undergo MRI. CT is useful for identifying necrotic bone in chronic infections. Ultrasound may be useful in children or those with sickle-cell disease. Bone scintigraphy is particularly useful for vertebral osteomyelitis. Finally, PET scan has demonstrated high sensitivity and specificity; however, its clinical application is limited by its high cost and poor availability. When used appropriately, diagnostic imaging can provide high sensitivity and specificity for detecting osteomyelitis, making radiological evaluation a crucial step in the diagnostic process of this debilitating condition.

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Остеомиелиттің сәулелік диагностикасының заманауи әдістеріне қысқаша шолу

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Түйіндеме

Остеомиелит - сүйек кемігінің инфекциясы нәтижесінде сүйек тінінің қабынуы. Өкінішке орай, бұл аурудың кеш диагнозы ықтимал асқынулардың қаупін күрт арттырады. Ал радиациялық диагностика әдістері дер кезінде дұрыс клиникалық диагноз қоюда маңызды рөл атқарады.

Бұл шолу мақаласында радиациялық диагностика әдістерінің әртүрлі түрлері салыстырылады, мысалы: рентген, компьютерлік томография, магнитті-резонанстық томография, ультрадыбыстық диагностика, сцинтиграфия, позитронды-эмиссиялық томография.

Оңтайлы пайдаланған жағдайда диагностикалық бейнелеу остеомиелитті анықтау үшін жоғары сезімталдық пен ерекшелікті қамтамасыз ете алады. Бұл осы күрделі аурудың диагностикасындағы рентгенологиялық зерттеулердің шешуші рөлін айқындайды.

Түйін сөздер: остеомиелит, рентген, МРТ, сцинтиграфия, ультрадыбыстық диагностика.

Краткий обзор современных методов радиологической диагностики остеомиелита

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Резюме

Остеомиелит – воспаление костной ткани в результате попадания инфекции в костный мозг. К сожалению, запоздалая диагностика данного заболевания резко увеличивает риск возможных осложнений. А лучевые методы диагностики играют важную роль в своевременном постановлении правильного клинического диагноза.

Данная обзорная статья сопоставляет разные виды методов лучевой диагностики, такие как: рентген, компьютерная томография, магнитно-резонансная томография, ультразвуковая диагностика, сцинтиграфия, позитронно-эмиссионная томография.

При правильном использовании диагностическая визуализация может обеспечить высокую чувствительность и специфичность при выявлении остеомиелита, что делает рентгенологическое исследование важнейшим этапом в диагностическом процессе этого тяжелого заболевания.

Ключевые слова: Остеомиелит, рентген, магнитно-резонансная томография, ультразвуковая диагностика, сцинтиграфия, позитронно-эмиссионная томография.