HK41: What imaging has the best ability to identify osteomyelitis in patients who have surgical site infection / periprosthetic joint infection?

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Response/Recommendation:

All the available imaging modalities, including conventional imaging as plain radiography, computer tomography (CT), magnetic resonance imaging (MRI), and WBC scintigraphy, have limited accuracy and should not be used as standalone tests to identify osteomyelitis.

Level of Evidence: **Limited**

Delegate Vote:

Rationale:

Identifying osteomyelitis in the context of surgical site infection (SSI) or periprosthetic joint infection (PJI) after hip or knee arthroplasty is critical, as proper debridement and complete removal of infected tissue are essential for effective treatment. While the use of the different imaging modalities to diagnose osteomyelitis in osteoarticular infections is well-described [1], given the lack of robust studies directly comparing different imaging modalities, there is no clear consensus on the ideal imaging strategy for identifying osteomyelitis in PJIs [2, 3]. The purpose of this systematic review was to determine the imaging examination with the best ability to identify osteomyelitis in hip or knee arthroplasty patients who have SSI or PJI, according to current literature.

We conducted a systematic literature search utilizing PubMed and Embase. Our search strategy included the use of Medical Subject Headings (MeSH) terms such as “hip arthroplasty,” “hip replacement,” “knee arthroplasty,” “knee replacement,” “osteomyelitis,” “prosthetic joint infection,” “surgical site infection,” “diagnostic imaging,” “conventional radiography,” “computed tomography,” “single photon emission computed tomography,” magnetic resonance imaging,” “positron emission tomography,” “nuclear imaging,” “bone scintigraphy,” “leukocyte imaging,” “ultrasound,” in each of the databases. We used the Boolean operators “AND” and “OR” to identify the intersection and union of terms. The database search yielded 2,193 articles, and after the initial screening of titles and abstracts, we identified 253 relevant articles. After full-text evaluation, 80 articles were selected for data extraction, including original studies, meta-analyses, reviews, and consensus articles.

Plain radiography, given its easy access and low cost, is usually the first diagnostic modality performed in PJI patients. However, plain radiographs have limited diagnostic value due to their low sensitivity and specificity [2]. In some instances, the presence of osteomyelitis may be speculated on radiographs, with periosteal reaction and signs of chronic infection; however, it is rather difficult to differentiate between other aseptic conditions. We did not find any articles suggesting plain radiography to identify the bony extension of infection in SSI/PJI; hence, we concluded that there is no evidence to support its use to assess osteomyelitis.

Ultasonography (US) is also an easily accessible, inexpensive modality that can evaluate fluid collections and soft-tissue involvement in the presence of infection. It can be used to facilitate joint aspiration or soft-tissue biopsy [4, 5]. However, the US cannot penetrate bone cortex or metallic components, limiting its use to the superficial soft tissues [6, 7]. We did not find any articles suggesting the assessment of osteomyelitis in SSI/PJI using the US, which made us conclude that there is no evidence suggesting the use of this modality in this context.

Computed tomography (CT) is more sensitive compared to plain radiography in detecting osteolysis, and bone destruction and identifying small osteolytic lesions [8]. Additionally, CT scans can assess soft-tissue abnormalities and recognize psoas abscesses that can mimic PJIs [9, 10]. However, CT sensitivity is limited in detecting infectious bony involvement. Cyteval et al. found that periprosthetic bone abnormalities cannot be distinguished by CT scan between aseptic and aseptic conditions, except for periostitis, which had 100% specificity, but only 16% sensitivity [11]. Although CT may play a role in the diagnosis of PJIs [3], our literature review did not identify any studies suggesting the standalone use of CT for the identification of PJI-related osteomyelitis.

Magnetic resonance imaging (MRI) can detect bone marrow changes, synovial lamellation, lymph node enlargement, and soft-tissue infection extension, but there is a lack of evidence to support its role in the assessment of PJIs. [12]. Metal-artifact-reduction software (MARS) sequences show some promising results [13], but the ability of MRI to evaluate osteomyelitis is limited in the presence of metallic implants [14]. An MRI shows a high negative predictive value (NPV) for excluding PJI or osteomyelitis if the bone marrow appears normal on all sequences; however, the positive predictive value (PPV) of this modality and its ability to differentiate osteomyelitis from other causes of marrow abnormalities is not as high. Reactive non-infectious marrow edema can occur adjacent to a site of an implant or soft-tissue infection, mimicking false-positive results for osteomyelitis [15]. Albano et al. reported that MRI features have limited accuracy in identifying infection in total hip arthroplasty (THA). They found that bone edema had 81.5% specificity, 76.3% sensitivity, 88% NPV, and 65.9% PPV for infection [16]. Another study reported 92.5% specificity, but only 47.4% sensitivity for PJI when bone destruction was examined on MRIs of THA patients [17]. We did not find evidence suggesting the use of MRI alone to detect secondary osteomyelitis in SSI or PJI.

Nuclear medicine techniques can sometimes be used to facilitate the diagnosis of PJI; however, little is known, to date, about their ability to assess the extent of osteomyelitis around implants.

Bone scintigraphy is typically performed using technetium-99m-labeled diphosphonates and it consists of three phases: assessing early perfusion, diffusion, and late bone uptake. It is a sensitive test (88 to 92%), but its specificity is low (50 to 70%) [18, 19]. It may present misleading abnormal findings for more than one year after prosthesis implantation [20]. Despite the limited specificity, it has a high NPV, making it a useful screening test to rule out infection [18, 21-23]. However, in the case of positive results, further assessment is warranted, as it cannot distinguish between osteomyelitis and normal postoperative changes, healing fractures, or aseptic loosening [24-26].

White blood cell (WBC) scintigraphy is considered the most reliable imaging study in the diagnosis of PJIs. This modality targets the leukocytes (mostly neutrophils) that migrate to the sites of infection and inflammation. In the case of a positive bone scan, it has traditionally been considered the next step in the assessment algorithm. However, interpretation of images may be challenging due to the normal accumulation of WBCs in the bone marrow, where distribution varies not only between individuals, but also within the same patient across different bone sites. Any condition that can change blood flow may alter the distribution of labeled WBCs [27]. Encouraging results have been reported in the identification of osteomyelitis in PJIs, although with wide variability [25, 28-32]. Meta-analyses data showed pooled sensitivity and specificity of 84 and 77% for total knee arthroplasty (TKA) and 92 and 88% for THA, respectively [33, 34]. The variability of outcomes has limited its use, but it may be helpful in conjunction with other exams. The WBC scintigraphy with bone marrow imaging (typically with ^{99m}TC sulfur colloid, 48 to 72 hours after WBC scan) can help to differentiate normal bone marrow from a site of infection, reducing the variability of radiotracer activity [35]. This test may be more accurate, with improved pooled sensitivity and specificity for PJI

(80 and 93% in TKA; 69 and 96% in THA, respectively)[33, 34]. However, bone marrow imaging makes the procedure more complex, increasing the time, the cost, and the radiation exposure of the exam, while this option is not widely available [24, 36, 37].

A F-Fluoro-2-deoxyglucose positron emission tomography (FDG-PET) represents an attractive alternative as it requires only one scan. Compared with WBC scintigraphy, it offers advantages such as time efficiency and increased resolution [38]. It is specific for neoplastic conditions, but it also accumulates at high glycolytic activity areas, as in inflammation and infection. Modern PET scans are performed with low-dose CT for anatomic localization and attenuation correction [27]. The FDG-PET has been shown to be highly sensitive in the detection of chronic osteomyelitis [39]. However, controversial results have been reported regarding their diagnostic value in PJIs; hence their utility is debated. This variability in outcomes may depend on the different imaging protocols and interpretation criteria used [36, 38, 40-42]. Nevertheless, most authors agree that its NPV is high, and it can be beneficial in cases of low probability of infection [43-45]. Meta-analyses data showed pooled sensitivity and specificity of FDG-PET in TKA PJIs to be 70 and 84% and in THA PJIs 86 and 93%, respectively [33, 34]. Similar findings have been reported by other studies [46, 47]. This test has an evolving role in PJI assessment, but may not represent the preferred nuclear imaging modality due to its higher cost and the fact that it does not seem to be more effective than WBC scintigraphy [1][34].

S*ingle-photon emission computed tomography/computed tomography (SPECT/CT)* also allows the correlation of scintigraphy results with anatomical images. It incorporates advanced algorithms that improve the quality of SPECT images using CT data (attenuation correction). This leads to a more accurate alignment of areas showing physiological variations or abnormal uptake with anatomical landmarks [48]. Some authors examined the usefulness of hybrid SPECT/CT in 99mTc–HMPAO–labeled leukocyte scintigraphy for bone and joint infections. They found that SPECT/CT differentiated soft-tissue involvement from bone involvement both in patients who have osteomyelitis and those who have orthopaedic implants[49]. Another group analyzed the added value of the 99mTc-antigranulocyte SPECT/CT in comparison with SPECT alone on planar imaging in low-grade PJIs. They found that PECT/CT images further demonstrate the extent of infection in the bone or bone marrow[50]. In a comparative study, the diagnostic performance of dual-isotope WBC/bone marrow SPECT/CT for PJI showed 100% sensitivity, 97 and 98%; accuracy, while the corresponding results for FDG PET-CT were 100, 71, and 79%, respectively. The authors stated that FDG PET-CT has appropriate accuracy, but the utility of its use in the diagnostic algorithm needs further evidence[51]. In the same manner, SPECT/CT has demonstrated promising results, but limited high-quality data support its use [27]. More high-quality studies are needed to explore further the potential of these modalities.

Conclusion:

Conventional imaging with CT and MRI offers high spatial resolution, visualizing the morphological alterations due to infection. They detect swelling, inflammation, and secondary effects of SSIs and PJIs, such as abscesses or soft-tissue alterations. However, their standalone use in the identification of osteomyelitis cannot be supported. Nuclear medicine modalities offer more reliable functional information related to the metabolic activity of infection, but may not be able to quantify the extent of bone involvement.

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