Imaging Diagnosis of Infected Total Knee Arthroplasty: A Comprehensive Review

Ana Isabel García-Valverde and Juan Francisco Hernández-Gómez

Ana Isabel García-Valverde, Department of Radiology, Hospital Universitario Virgen del Rocío, Seville, Spain.

Abstract

There are a series of complementary imaging tests that can help us confirm our diagnosis of prosthetic knee infection. They are plan films, fistulography, echography, bone scintigraphy, computerized tomography scan (CT scan), magnetic resonance imaging (MRI) and PET (positron electron tomography). Plain radiographs and echography are neither sensitive nor specific and CT scan and MRI can be limited by hardware-induced artifacts. Bone scintigraphy is not affected by orthopedic hardware and is the current imaging modality of choice for suspected total knee arthroplasty (TKA) infection. Bone scintigraphy is sensitive for identifying the failed TKA, but cannot be used to determine the cause of failure. SPECT/CT should be part of the routine diagnostic algorithm for patients with pain after TKA. The presence of lamellated hyperintense synovitis at MRI of TKA had a high sensitivity and specificity for infection. The current role of PET is still controversial but could be an appropriate alternative for assessing these patients.

Keywords: total knee arthroplasty, infection, diagnosis by imaging, plain radiographs, echography, bone scintigraphy, CT scan, MRI, PET

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8.1 Introduction

There are a series of complementary imaging tests that can help us confirm our diagnosis of prosthetic knee infection [1]. In this chapter we review the role of imaging tests in the follow-up of patients with a potential total knee arthroplasty (TKA) infection. We revise the role of plan films, fistulography, echography, bone scintigraphy, computerized tomography scan (CT scan), magnetic resonance imaging (MRI) and PET (positron electron tomography) in the diagnosis of the infected TKA.

8.2. Plain Films

Conventional radiographs (X-ray) are the initial radiologic study in most suspected knee disorders.

When examining a TKA, we should carry out periodic X-rays. The appearance of rapidly-progressing radiolucent lines around the implant should make us suspect an infection. The resorption of subchondral bone and patchy osteoporosis can also be elements of suspicion. The presence of osteolysis is normally the most usual one, although the type of osteolysis found is normally fairly unspecific (Fig. 8.1).

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8.3 Fistulography

In cases where a suppurating fistula is present, a fistulography could demonstrate continuity between the fistulous tract and the deep tissues and the prosthesis (Fig. 8.2a). It is very useful in the assess of the abscess

periprosthetic with fistulous tract (Fig. 8.2b, Fig. 8.2c and Fig. 8.2d).

8.4 Ultrasonography (US)

In revision arthroplasty, a pre-surgical US can be useful to visualize the relationship between the prosthesis and the popliteal vascular bundle (Fig. 8.3a). US can also evaluate the interface bone-prosthesis in the marginal areas related to subluxations and/or sustentation defects (Fig. 8.3b).

US can be used to assess joint effusions. US as a diagnostic technique that permit the differentiation between effusion and synovial thickening (Fig. 8.3c). The normal synovium is a thin membrane. When it becomes inflamed, diffuse or nodular thickening of the membrane is seen, which may show increased vascular flow on Doppler US. The US is very useful to diagnosis soft tissue swelling, to follow the progression or regression and to diagnosis abscess periprosthetic (Fig. 8.3d).

The US Doppler can also be used to evaluate complication vascular and

nervious (Fig. 8.3e and 8.3f).

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8.5 Bone Scintigraphy

Bone scintigraphy is not affected by orthopedic hardware and is the current imaging modality of choice for suspected joint replacement infection (Fig. 8.4). Bone scintigraphy is sensitive for identifying the failed TKA, but cannot be used to determine the cause of failure.

In 1990 Rand et al [2] reported that Indium 111(111 In) leukocyte scanning had an accuracy of 84%, a sensitivity of 83%, and a specificity of 85%. In 1997 Nijhof et al [3] found that the she sensitivity of indium-111-labeled immunoglobulin G (In-111-IgG) scintigraphy for infection was 1.0, for TKA the specificity was 0.5. In-111-IgG was shown to be a highly sensitive and fairly specific tool for detecting of late infection of TKAs.

In 2001 Van Acker et al [4] compared fluorine-18 fluorodeoxyglucose PET (FDG-PET), technetium-99m hexamethylpropylene amine oxime (HMPAO)labelled white blood cell (WBC) scintigraphy and bone scintigraphy in the assessment of painful TKAs. It was concluded that WBC scintigraphy in combination with bone scintigraphy had a high specificity in the detection of infected TKAs. FDG-PET seemed to offer no additional benefit.

In 2000 Teller et al [5] compared preoperative sequential imaging with joint aspiration and clinical assessment during revision TKA. Sequential technetium99-hydroxymethyl diphosphonate and indium-111 leukocyte imaging was 64% sensitive and 78% specific. Positive scintigraphy increased the likelihood of finding infection intraoperatively from 14% to 30%, although negative scintigraphy decreased this likelihood to 7%. Based on this study, the routine use

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of sequential technetium-99-hydroxymethyl diphosphonate and indium-111 leukocyte imaging was not recommended for differentiating occult infection from mechanical failure in painful, loose TKA.

In 2000 Scher et al [6] analyzed the predictive value of indium-111 leukocyte scans in the diagnosis of infected TKA. The results of this study suggested limited indications for the use of the indium-111 scan in the evaluation of painful TKA. A negative indium scan may be helpful in suggesting the absence of infection in cases in which the diagnosis is not otherwise evident. Indium scans were found to have a 77% sensitivity, 86% specificity, 54% and 95% positive and negative predictive values, and 84% accuracy for the prediction of infection.

In 2001 Joseph et al [7] investigated the reliability of combined indium-111 leukocyte/technetium-99m sulfur colloid scans, with and without the addition of blood pooling and blood flow studies, in the diagnosis of infected TKA. Routine use of these radionuclide scans was not supported by this study. Results for imaging alone included 100% specificity, 46% sensitivity, 100% positive predictive value, 84% negative predictive value, and 88% accuracy. Inclusion of blood pooling and flow phase data improved results to 66% sensitivity, 89% negative predictive value, and 90% accuracy, with reductions in specificity (98%) and positive predictive value (91%).

In 2002 Larikka et al [8] evaluated the usefulness of 99mTc labelled ciprofloxacin imaging in detecting the presence of infection in patients with symptomatic TKAs. 99mTc-ciprofloxacin imaging showed diagnostic sensitivity of 86% and a specificity of 78% for correctly classifying the presence of infection. This study

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indicated that 99mTc-ciprofloxacin imaging may be used in the diagnosis of TKA infections.

In 2004 von Rothenburg et al [9] evaluated the diagnostic accuracy of Tc-99mlabeled antigranulocyte antibody Fab' fragments in infected total arthroplasty. They found a sensitivity of 93%, a specificity of 65%, and a positive predictive accuracy of 63%. There was a negative predictive accuracy of 94%. The high negative predictive accuracy in the whole group suggested that the scan can be used to exclude infection in most cases.

In 2008 Rubello et al [10] evaluated the clinical efficacy of a dual-time acquisition protocol consisting of early 4 hours and delayed 20-24 hours imaging with anti-granulocyte scintigraphy (LeukoScan) in the diagnosis of infection in painful TKA. The results of this study suggested that delayed LeukoScan imaging was important in identifying false positive results detect at early imaging. Thus, a dual-time, 4 hours early and 20-24 hours delayed LeukoScan imaging approach should be recommended to increase the
diagnostic accuracy of the scintigraphy, with the exception of patients with a negative early LeukoScan examination, in whom the acquisition of delayed imaging appears unnecessary. Concomitant antibiotic therapy did not influence the diagnostic value of LeukoScan.

In 2012 Gratz et al [11] compared the diagnostic accuracy of imaging using an intact murine antigranulocyte antibody 99mTc-besilesomab, and a murine antibody Fab fragment 99mTc-sulesomab, in patients with suspected septically

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loosened TKA. At 4 and 24 hours after intravenous injection, absolute uptake of 99mTc-besilesomab was significantly higher than 99mTc-sulesomab in infected knee joints. Infected-to-healthy knee activity ratios were similar at 4 and 24 hours for 99mTc-besilesomab and 99mTc-sulesomab. Both 99mTcbesilesomab and 99mTc-sulesomab had similar diagnostic accuracy for the detection of septic arthroplasty. If repeated use of immunoscintigraphy is needed for follow-up, 99mTc-sulesomab should be preferred over 99mTcbesilesomab since it is known to be well tolerated and without side effects or incompatibility reactions.

In 2014 Ouyang et al [12] investigated the diagnostic validity of three-phase bone scintigraphy (TPBS) for diagnosing prosthetic joint infection (PJI) in cases of suspected infected total joint arthroplasty. They performed a systematic review and meta-analysis to define pool sensitivity, specificity, diagnostic odds ratios (DORs), positive likelihood ratios (PLR), negative likelihood ratios (NLR), the area under the receiver-operating characteristic curve (AUC), and post-test probability. Heterogeneity and publication bias were assessed, and subgroup and meta-regression analyses were conducted. The pooled sensitivity and specificity for using TPBS to detect PJI was 0.83 and 0.73, respectively. The AUC, PLR, NLR, and DOR were 0.85, 3.1, 0.23, and 14, respectively. Low clinical scenario-negative post-test probabilities were 7 %, and high clinical scenario-positive post-test probabilities were 90 %. Subgroup analyses indicated that the sensitivity and specificity of TPBS for

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detecting infected arthroplasty of the hip (0.81 and 0.78, respectively) were significantly higher than those of the knee (0.75 and 0.55, respectively). There was no significant evidence of publication bias. The main conclusion was that TPBS had reasonable diagnostic value for detecting PJI and could be performed as a screening test or part of preoperative tests and analyzed in conjunction with other findings at the time of suspected PJI.

In 2014 Basu et al [13] compared the value of FDG PET with combined Inlabeled leukocyte/Tc-sulfur colloid bone marrow (WBC/BM) imaging for diagnosing infection in hip and knee prostheses. The sensitivity, specificity, positive predictive value, and negative predictive value of FDG PET in knee prostheses were 94.7%, 88.2%, 69.2%, and 98.4%, respectively. The sensitivity, specificity, positive predictive value, and negative predictive value of WBC/BM imaging in knee prostheses were 33.3%, 88.5%, 25.0%, and 92.0%, respectively. The main conclusion was that the diagnostic performance of FDG PET scan in detecting infection in painful knee prostheses is optimal for routine clinical application. Considering the complexity and costs of WBC/BM imaging and related safety issues associated with this preparation, FDG PET seems to be an appropriate alternative for assessing these patients.

8.6 Computerized Tomography (CT) Scan

CT scan can play a role in the diagnosis of the infected TKA (Fig. 8.5). Bone single photon emission computed tomography (SPECT)/CT is considered as beneficial in unhappy patients with pain, stiffness or swelling after total knee

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arthroplasty (TKA). In 2015 Hirschmann et al [14] reported typical patterns of bone tracer uptake (BTU), distribution and intensity values in patients after TKA. SPECT/CT changed the clinical diagnosis and final treatment in 85/100 (85%) knees. Intraoperative findings confirmed the preoperative SPECT/CT diagnosis in 32/33 knees (97%). TKA loosening as well as progression of patellofemoral osteoarthritis (OA) was correctly diagnosed in 100% of knees. Typical patterns of BTU for specific pathologies were identified. Loose femoral TKA components significantly correlated with increased BTU at the lateral femoral regions. Loose tibial TKA components significantly correlated with increased BTU at all tibial regions and around the tibial peg. The diagnostic benefits of SPECT/CT in patients after TKA were proven. Typical pathology-related BTU patterns were identified.

8.7 Magnetic Resonance Imaging (MRI)

In MRI studies, the initial synovial reaction is associated with synovial hypertrophy. The metallic prostheses and debris postsurgical produce additional magnetic susceptibility artifacts (Fig. 8.6, a, b, c and d).

Synovial hypertrophy is usually intermediate signal on T1- and T2-weighted images, enabling differentiation from fluid within the joint. However, active synovitis may show signal characteristics similar to that of fluid. Enhancement of the synovium with intravenous contrast media may theoretically help distinguish active synovitis from fibrotic synovium

In 2013 Plodkowski et al [15] investigated the sensitivity and specificity of lamellated hyperintense synovitis for infection following TKA and determined the

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inter- and intraobserver variability of this sign at MRI. MRI images from 28 patients with proved infected TKA and 28 patients with noninfected TKA were reviewed by two musculoskeletal radiologists for the presence of lamellated hyperintense synovitis. Cases were rereviewed 2 weeks later by each reader. The sensitivity and specificity were calculated with the initial reads. The κ statistic was used to assess inter- and intraobserver reliability. The sensitivity of lamellated hyperintense synovitis for infection was 0.86-0.92 and the specificity was 0.85-0.87. There was almost perfect interobserver agreement and intraobserver agreement in the classification of the synovial pattern. The presence of lamellated hyperintense synovitis at MRI of TKA had a high sensitivity and specificity for infection. This sign had high inter- and intraobserver reliability.

8.8 Positron Electron Tomography (PET)

FDG-PET seems to be an appropriate alternative for assessing patients with an infected TKA. As mentioned above, Van Acker et al [4] compared FDG-PET, 99mtc-HMPAO white blood cell SPET and bone scintigraphy in the evaluation of painful TKAs. It was concluded that WBC scintigraphy in combination with bone scintigraphy had a high specificity in the detection of infected TKAs, and that FDG-PET seemed to offer no additional benefit (Fig. 8.7).

As previously mentioned, Basu et al [13] analyzed the role of FDG-PET for diagnosing infection in hip and knee prostheses, and compared FDG-PET with combined (111)In-labeled leukocyte/(99m)Tc-sulfur colloid bone marrow imaging. It was concluded that the diagnostic performance of FDG-PET scan in detecting infection in painful knee prostheses was optimal for routine clinical

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application. Considering the complexity and costs of WBC/BM imaging and related safety issues associated with this preparation, FDG-PET seemed to be an appropriate alternative for assessing these patients.

8.9 Conclusions

Differentiating aseptic loosening, the most common cause of TKA failure, from infection, is important because their treatments are very different. However, many times differentiating between these 2 entities is difficult. Plain radiographs and ultrasonography (US) are neither sensitive nor specific and CT scan and MRI, can be limited by hardware-induced artifacts. Bone scintigraphy is not affected by orthopedic hardware and is the current imaging modality of choice for suspected joint replacement infection. Bone scintigraphy is sensitive for identifying the failed TKA, but cannot be used to determine the cause of failure. SPECT/CT should be part of the routine diagnostic algorithm for patients with pain after TKA. The presence of lamellated hyperintense synovitis at MRI of TKA had a high sensitivity and specificity for infection. The current role of FDGPET is still controversial but could be an appropriate alternative for assessing these patients.

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