

**American College of Radiology
ACR Appropriateness Criteria®**

Clinical Condition: **Imaging After Total Knee Arthroplasty**

Variant 1: **Pain after TKA: initial evaluation.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee	9	Standing views of both legs can be used to assess the mechanical axis of both lower extremities.	Min
X-ray knee fluoroscopy	1		Min
CT knee	1		Min
MRI knee	1		None
NUC bone scan targeted	1		Med
FDG-PET knee	1		High
INV aspiration knee	1		IP
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Variant 2: **Pain after TKA: positive aspiration for infection.**

Radiologic Procedure	Rating	Comments	RRL*
CT knee	1		Min
MRI knee	1		None
NUC bone scan targeted	1		Med
NUC Ga-67 scan lower extremity	1		High
NUC Tc-99m bone scan and In-111 WBC scan	1		High
NUC In-111 WBC and sulfur colloid scan	1		High
FDG-PET knee	1		High
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

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Clinical Condition:**Imaging After Total Knee Arthroplasty****Variant 3:****Pain after TKA: positive radiograph for loosening. Negative aspiration for infection.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee fluoroscopy	1		Min
CT knee	1		Min
MRI knee	1		None
NUC bone scan targeted	1		Med
FDG-PET knee	1		High
X-ray arthrography knee	1		Min
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Variant 4:**Pain after TKA: negative radiograph for loosening. Negative aspiration for infection.**

Radiologic Procedure	Rating	Comments	RRL*
CT knee	7	For osteolysis or component malposition.	Min
NUC bone scan targeted	6	Reasonable screening test.	Med
NUC In-111 WBC and sulfur colloid scan	6	If persistent high clinical suspicion of infection.	High
MRI knee	5	Expensive, less experience than other tests.	None
X-ray knee fluoroscopy	2		Min
NUC Ga-67 scan lower extremity	1		High
NUC Tc-99m bone scan and In-111 WBC scan	1		High
FDG-PET knee	1		High
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Variant 5:**Routine follow-up of asymptomatic patient with TKA.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee AP/lateral standing and tangential patellar views	9		Min
X-ray knee tunnel views	1		Min
X-ray knee fluoroscopy	1		Min
CT knee	1		Min
MRI knee	1		None
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

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IMAGING AFTER TOTAL KNEE ARTHROPLASTY

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Summary of Literature Review

Total knee prostheses have been used clinically since the late 1960s [1] and more than 350,000 primary and revision knee replacements are now performed each year [2]. Patient satisfaction is greater than 90%, and there is a reported survival of the implants of greater than 90% at 10-15 years [3]. Nonetheless, failures do occur, and more than 22,000 knee revision surgeries are performed yearly [3]. Sharkey et al reviewed the causes of failure of 212 consecutive revision total knee replacements performed between September 1997 and October 2000 [3]. The most common causes of failure were polyethylene wear (25%), aseptic loosening (24.1%), instability (21.2%), infection (17.5%), arthrofibrosis (14.6%), malalignment or malposition (11.8%), and extensor mechanism deficiency (6.6%). Early failure (before 2 years) was due in 50% of cases to instability, malalignment, malposition or failure of fixation. The most common cause of failure in the early group was infection (25.4%). Late failure was usually the result of wear, loosening, or instability.

Routine Imaging

Radiography

The timing of postoperative radiographs has been evaluated in an effort to decrease costs. Postoperative in-hospital radiographs are thought unnecessary if the surgery was uncomplicated [4]. Baseline radiographs are suggested at the first outpatient visit (eg, at 6 weeks).

The effectiveness of radiographs obtained upon admission to a rehabilitation facility following hip or knee arthroplasty has been studied by Lee et al [5]. This retrospective review examined the charts of 209 patients admitted after total knee replacement and found 2 patients (0.95%) had abnormal findings on radiographs. There was no change in the length of hospital stay or the medical

intervention required in these patients, leading the authors to conclude that routine radiography upon admission to a rehabilitation facility after knee replacement surgery is not cost effective.

Later follow-up is directed toward identifying any of the complications discussed below, particularly loosening.

Complications

Identification of the cause of a painful (TKA) is important preoperatively since "...re-operation is unwise and frequently associated with suboptimal results" in cases of unexplained pain [6].

Loosening

In one series, loosening was a cause of revision in 34% of cases performed 2 years or more after implant insertion [3]. Duff et al [7] defined loosening on radiographs by the presence of prosthetic fracture, cement fracture, periprosthetic fracture, or gross component migration. Assessment of radiolucent lines has been an important tool in defining fixation and therefore, conversely, loosening. Loosening is suggested when 1) there is progressive widening of a lucent zone on follow-up examinations, 2) there is greater than a 2mm wide lucent zone at the cement bone interface or any lucency at the metal-cement or metal-bone interface, or 3) the lucent zone is extensive, especially if around the pegs or stem of a component [2]. These lucent lines should be distinguished from more diffuse bone loss that occurs in areas of decreased stress ("stress shielding").

Fluoroscopy may be useful to see lucent lines in profile that could be obscured on standard anterior-posterior (AP) radiographs [2,8].

Bone scintigraphy may be helpful in diagnosing loosening, especially when obtained many years after surgery. This delay in maximum utility is due to the observation that positive bone scans are noted in 20% of asymptomatic knees a year after surgery and in 12.5% of individuals 2 years postoperatively [9]. Generally, increased isotope uptake on the static scan but not on the blood pool scans is thought more likely due to loosening than to infection [10]. Normal scans are most helpful, indicating that loosening or infection is unlikely. Evaluation of 80 bone scans in patients with symptomatic TKAs found that the method distinguished abnormal patients (loosening or infection) from normal ones (sensitivity of 92.3%) but was unable to distinguish between these two abnormal conditions [10]. The negative predictive value (NPV) of 95% made a normal scan reassuring. Serial bone scans may be more helpful than a single examination [11].

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Infection

Infection occurs in 1%-4% of TKAs [12] and may be acute or delayed. Late infection has been defined as occurring at least 3 months post surgery [13]. In one series, infection was responsible for 25.4% of early revisions and 7.8% of revisions performed more than 2 years after the initial operation [3]. Early acute infections after TKA are usually clinically evident by pain, swelling, fever, systemic symptoms, and erythema [7]. *Staphylococcus epidermidis* and *staphylococcus aureus* are the most common organisms associated with these infections [7]. Low grade or chronic infections may be more difficult to identify [7]. Duff et al [7], for example, noted that the diagnosis of infection was not obvious in 53% of knees prior to revision arthroplasty.

Clinical Features

Pain is the most common presenting symptom; however, it is a nonspecific finding [14]. Night pain or pain at rest is typical of infection, whereas pain on weight bearing is more consistent with mechanical loosening. Some authors suggest that infection be excluded in all patients with persistent pain more than 6 months following joint replacement [7].

Loosening may result from infection [14]. A knee may be infected without the presence of fever, chills, erythema, or swelling [7].

Laboratory

Laboratory findings are often nonspecific. Peripheral leukocyte counts are not elevated in most patients with infected prostheses [7]. Sedimentation rates are abnormal in patients with infection but this finding may also be seen in uninfected patients, limiting the value of the test [7,15]. A retrospective review of 68 patients undergoing hip and knee revision surgery indicated that C reactive protein (CRP) was significantly higher in patients with infection compared to those with loosening (sensitivity 79% for all prostheses), although a normal level did not exclude infection [12]. A large multicenter study found CRP and joint aspiration to be the most useful tools to diagnose infection [16].

Aspiration

Knee joint aspiration has been found to be extremely useful in diagnosing joint infection after TKA [17]. Duff et al [7] found a sensitivity, specificity, and accuracy of 100% for aspiration in a series of 43 knees with pain, instability, loosening, or suspected infection undergoing surgical revision. In contrast, radiographic findings did not separate infected from noninfected patients. Virolainen et al [12] found joint aspiration to be 100% specific and 75% sensitive for diagnosing infection and to be the best test for diagnosing infection in a group of total hip and knee replacement patients. Bach et al [13] found that early aspiration led to a significant reduction in the duration of treatment and a better outcome. In 16% of

patients, more than 3 aspirations were necessary to obtain a positive culture. Barrack et al [18] noted that in contrast to aspiration of total hip replacements where false positive results are more common, aspirations of knee joints are more often falsely negative. This was thought to most often result from antibiotic treatment [18]. At least 2 weeks off antibiotics is recommended before the aspiration is performed (with careful clinical monitoring for sepsis), but as long as a month may be necessary for cultures of aspirated fluid to become positive [18]. Therefore, a repeat aspiration should be done weekly if the first aspiration is negative and clinical suspicion for infection remains high [18]. Even with a negative preoperative aspiration, intra-operative tissue may indicate infection [14]. Bernard et al [16], after literature review and a multicenter trial, advocated CRP and joint aspiration as the best tools for diagnosing prosthetic joint infection. When CRP level is greater than 10 mg/l, repeat joint aspiration or biopsy is suggested.

Radiographs

Duff et al [7] found radiographs not to be helpful since loosening, periostitis, focal osteolysis, and radiolucent lines were seen in both infected and uninfected knees. Most importantly, infection may be present with a “normal” radiographic appearance.

Bone Scan

It is usually stated that bone scintigraphy is useful for excluding infection but of limited value in detecting it [19]. Thus sensitivity is high and specificity is low.

Increased uptake may persist on bone scan even at 2 years after surgery [9]. Infection is more likely than aseptic loosening if there is increased uptake on both blood pool and delayed images [10]. Analysis of 80 bone scans in patients with postoperative pain found that no patient with infection had a negative scan [10]. Patients with abnormal scans should be further assessed [20].

White Blood Cell Scan

White blood cells (WBCs) may be labeled with technetium-99m or indium-111 [21]. Leucocyte scanning using indium-111 was introduced in the 1980s. Labeling leukocytes with indium-111 requires that the patient's venous blood sample be drawn and the WBCs isolated and labeled with indium-111 oxine [22]. Indium-labeled WBCs are then injected intravenously prior to scanning [22]. Accurate interpretation requires comparison of the indium isotope uptake to activity on bone scan; a positive indium scan for infection generally requiring increased indium-111 uptake either in a different distribution (an “incongruent” scan) or in greater intensity than on the bone scan [22]. Indium labels both acute and chronic WBCs, and this may account for positive scans in other conditions in which inflammatory changes may be present, such as particle disease [22]. A small sample of indium scans in uncomplicated postoperative TKA

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patients also showed that inflammation can persist around the operative site [22].

Scher et al [22] evaluated patients with loose or painful knee prostheses and found a sensitivity of 88%, specificity of 78%, positive predictive value (PPV) 75% and NPV of 90% for infection. The examination was not recommended as routine because of the expense, complexity and limited sensitivity, specificity, PPV, and accuracy. In equivocal cases, and when an experienced musculoskeletal pathologist is not available to interpret an intra-operative frozen section, these authors noted that a negative indium scan may be helpful to suggest the absence of infection.

Evaluation of indium scanning may lead to a high false positive rate that is thought to be due to marrow packing [19]. The addition of technetium-99m-labeled sulfur colloid scanning has been investigated to reduce this. Joseph et al [19], however, found that low sensitivity and the potential for false negative results made this combination of scans of limited utility for diagnosing prosthetic infection, and therefore it is no longer used in their institution. In that group of 22 total knee prostheses evaluated and later operated upon, there was a sensitivity of 66%, specificity of 100%, PPV of 100%, NPV of 88%, and accuracy of 91%. The addition of blood pool and flow scans was investigated to determine if hyperemia led to a match of bone indium uptake (and therefore, a falsely negative scan). These additional scans decreased the number of false negative findings (sensitivity of 83%, specificity of 94%, PPV of 83%, NPV of 94%). Overall, however, the performance of the indium/colloid scan protocol was again thought to be of limited clinical utility [19]. Semiquantitative assessment of WBC scans has, however, produced > 90% sensitivity and specificity in one series [21]. Magnusen et al noted that positive indium WBC scan and sedimentation rates were the most predictive variables for detecting septic prostheses [15].

A study of a small series of total knee arthroplasties using indium-111 IgG found the sensitivity of this agent for infection to be high but its specificity low (sensitivity 100%, specificity 50%) [23]. Bernard et al [16] reported a multicenter trial of various methods for diagnosing hip and knee infections. Scans using tagged white cells or radiolabelled immunoglobulin demonstrated a sensitivity of 74% and specificity of 76% for diagnosing infection [16]. Literature review indicates sensitivities of 38%-100% and specificities 41%-100% for WBC scans of joint prostheses [12,16,24-27]. These studies were, therefore, (as noted above) not recommended as routine for differentiating mechanical failure from occult infection in painful loose total knee prostheses [16].

FDG-PET

Zhuang et al [28] cite reports indicating that elevated glycolytic activity causes inflammatory cells such as

neutrophils and activated macrophages to be FDG avid at sites of inflammation and infection. Thus, FDG-PET imaging may be useful for detecting infection after joint replacement. The examination is much faster (a few hours) and less expensive than combined bone, marrow, and indium scintigraphy [28]. In one series, the use of FDG-PET scanning combined with bone scanning showed no advantage over HMPAO-labeled WBC scan and bone scanning [29]. Another study of 36 painful knee prostheses examined using 18F-FDG-PET scanning showed identification of 10 of 11 infected cases but false positive results in 7 cases (sensitivity of 90.9%, specificity of 72%, and accuracy of 77.8% for detecting infection) [28]. This was lower accuracy than for assessment of hip prostheses. The cause for the high number of false positives was not known. Stumpe et al [30], found diffuse synovial and focal extrasynovial FDG-PET uptake in patients with component malrotation. They concluded that this test is noncontributory in individual patients with persistent pain.

Wear

Polyethylene thickness-The polyethylene articular surface of a total knee prosthesis may undergo true wear, deformation, and creep that lead to a decrease in the thickness of the polyethylene; these may be clinically referred to as "wear"[31]. Several methods have been used to study the thickness of the polyethylene and thus the extent of wear.

Collier et al [31] examined single leg standing frontal radiographs of the knees for assessing of polyethylene thickness. Two types of measurement were made: 1) minimum distance from the metallic femoral condyle to the metal backing baseplate, and 2) minimum distance from the metallic femoral condyle to a line through the top surface of the baseplate at its widest dimension. The latter method proved more accurate and less affected by tilting of the tibial component. Overall, 87% of measurements using the second method were within 1 mm of the known implant thickness (accuracy roughly +/- 1 mm initially). However, accuracy decreased for evaluating polyethylene thickness in patients with wear requiring revision.

Because of the tilt of the tibial component in some cases, fluoroscopy has been used to align radiographs perpendicular to the joint surface. This allows measurement of the thickness of the polyethylene liner so that decreases in liner thickness (indicating wear) can be measured. Correction for magnification is made using the known diameter of a portion of the tibial component. In-vivo assessment has shown repeatability (precision) of these measurements to be 0.2mm with a 99% confidence level [32]. The major source of variation is angulation of the tube in the craniocaudal direction; a 0.33 mm (6.5%) change in mean insert thickness is seen per degree of

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angulation. Hoshino et al [33] note that the magnification error cannot be reduced to ≤ 1 mm using fluoroscopy.

Varus/valgus stress has been added to the fluoroscopic examination to improve evaluation of polyethylene thickness [34]. The coefficient of variation for repeat examination was 3.4%.

Granulomas-Oblique posterior femoral condylar radiographs have been recommended for evaluating the posterior condyles after TKA [35,36]. This method was thought to be especially helpful when a posterior stabilized prosthesis is in place.

Sonography is under investigation for evaluating the thickness of polyethylene liners [37] but is not in general use.

Focal osteolysis due to wear particles may be visible on radiographs, and routine surveillance has been suggested even in asymptomatic patients for this assessment [36]. In one study, focal osteolysis was defined as an isolated area of lucency measuring at least 3 mm in diameter [7]. It may be difficult to differentiate these lytic defects from stress shielding (osteoporosis).

Computed Tomography

Math et al [2] recommend using computed tomography (CT) examination in patients with painful knee prostheses and equivocal radiographs, particularly for:

1. Loosening: to show the extent and width of lucent zones that may be less apparent on radiographs.
2. Osteolysis: CT is superior to radiographs for this diagnosis. These authors recommend CT be obtained in patients with painful knee prostheses with normal or equivocal radiographs and increased uptake on all three phases of a bone scan to look for osteolysis.
3. Assessing rotational alignment of the femoral component.
4. Detecting subtle or occult periprosthetic fractures.

Arthrography CT may be useful in documenting large displaced polyethylene fragments. In one case, arthrography CT allowed identification of the nonopaque polyethylene fragment of the tip of a posterior stabilized prosthesis [38].

Magnetic Resonance Imaging

Improved pulse sequences and techniques have facilitated the evaluation of the periprosthetic soft tissues and bone, allowing demonstration of focal osteolysis and inflammatory synovitis, as well as ligament and tendon abnormalities [39-41].

Patellar Complications

Patellar complications include subluxation, dislocation, fracture [42], component loosening or wear, impingement, and osteonecrosis [1]. Radiographs are

usually satisfactory for diagnosing patellar complications [2]. Malposition of femoral and tibial components may affect patellar alignment [43]. The rotation of tibial and femoral components may be evaluated on CT examination using anatomical landmarks [2,43,44]. MRI may also allow this evaluation [45].

Patellar fractures occur in up to 3.8% of patients [1], usually within the first few postoperative years [1]. Most are not associated with prior injury, and many are asymptomatic, highlighting the importance of radiography for their identification [1]. Risk factors include older age, osteonecrosis, lateral release, surgical technique, incorrect prosthetic alignment (femorotibial or patellofemoral), and improper patellar resection [1]. Transverse fractures are thought to be associated with patellar maltracking, while vertical fractures often occur through a fixation hole [1].

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document.

Relative Radiation Level Designations	
Relative Radiation Level*	Effective Dose Estimate Range
None	0
Minimal	< 0.1 mSv
Low	0.1-1 mSv
Medium	1-10 mSv
High	10-100 mSv

*RRL assignments are not included for some examinations. The RRL assignments for the IP (in progress) exams will be available in future releases.

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An ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those exams generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.