Imaging Evaluation of Knee Arthroplasty

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After participating in this educational activity, the diagnostic radiologist should be better able to diagnose complications of total knee arthroplasty.

Key Words: Knee Arthroplasty, Imaging of Knee Arthroplasty, Complications of Knee Arthroplasty

The objectives of this article are: (1) to review various types of knee arthroplasties; (2) to discuss the normal post-operative appearance of knee arthroplasty on conventional radiographs and other imaging modalities; (3) to recognize the radiologic findings related to the most frequent complications of knee arthroplasties; and (4) to understand the value of various imaging modalities in the evaluation of knee pain in a patient with a knee arthroplasty.

Total knee arthroplasty (TKA) is one of the most clinically successful and cost-effective medical procedures developed during the last half of the 20th century. Multiple types of knee arthroplasty are in use. Total knee implants can be posterior cruciate ligament (PCL)-retaining, PCL-substituting, varus-valgus constrained, and rotating-hinge types. TKA also is used with metal block augmentation for bone defects of the medial or lateral tibia, for medial pivot knee, for high-flexion knee, and for sex-specific knee.1

Hemiarthroplasty, or unicompartmental arthroplasty (UKA), can replace the medial, lateral, or patellofemoral compartments.

 Requirements for PCL-retaining TKA include good quality of the bone with minimal defects, intact soft tissues, and a PCL that remains functional.

PCL-substituting TKA is indicated in patients with deficient or absent PCL, previous patellectomy (weak extensor mechanism that may predispose to anterior instability), and inflammatory arthritis. On radiographs PCL-substituting TKA can be differentiated from a PCL-retaining TKA by the presence of a polyethylene tibial post (may be radiolucent), femoral cam (i.e., a special bar in the femoral component into which the tibial post fits), and deeply dished polyethylene articular surfaces of the tibial component.

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Varus-valgus constrained TKA has a tall tibial post and a deep femoral box (i.e., a slot in the femoral component into which the tibial post fits), and it may have an extended tibial stem into the tibial medullary canal. The purpose of the tibial post is to limit varus-valgus tilt, posterior subluxation, and internal/external rotation.

TKA with metal block augmentation is used for bone defects of the medial or lateral tibia.

UKA may have fixed or mobile bearing (a polyethylene insert that articulates with a metallic femoral component and a metallic tibial tray, also called a meniscal bearing).2,3

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Patellar Component Tilt, Subluxation, and Dislocation

Patellar component tilt is defined as the angle formed between the patellar bone-prosthesis interface and a line drawn across the anterior femoral condyles on the patellar (Merchant) view. A patellar tilt greater than 5 degrees is indicative of patellofemoral instability.

Patellar component tilt, subluxation, and dislocation risk factors include preoperative valgus deformity, incorrect tracking (i.e., shifting) of the patella after replacement, malrotation of the tibial or femoral components, and postoperative lateral retinacular tightness (Figure 1).4

Periprosthetic Fractures: Femur

The most common site of a periprosthetic fracture of a TKA is the supracondylar area of the distal femur. Risk factors that may predispose a patient to femoral fracture include osteoporosis, anterior femoral cortical notching, chronic corticosteroid use, advanced age, female gender, and neurologic disorders. Inaccurate sagittal orientation that places the femoral component in too much extension may notch the anterior femur, acting as a stress riser that later may result in a supracondylar fracture of the femur.

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Highest stress concentration occurs with anterior femoral cortical notches greater than 3 mm in depth, and sharp corners and notches located directly at the proximal end of the femoral implant (Figure 2).

Tayside classification of anterior femoral cortical notching is:

- Grade I: violation of the outer table of the anterior femoral cortex;
- Grade II: violation of the outer and the inner table of the anterior femoral cortex;
- Grade III: violation up to 25% of the medullary canal (from the inner table to the center of the medullary canal); and
- Grade IV: violation up to 50% of the medullary canal (from the inner table to the center of the medullary canal) and unclassifiable.5

Periprosthetic Fractures: Tibia

Periprosthetic tibial fractures frequently are associated with loose prosthetic components and malalignment or malposition of implants (Figure 3). Intraoperative tibial fracture is an uncommon complication of primary TKA.6

Periprosthetic tibial fractures frequently are associated with loose prosthetic components and malalignment or malposition of implants.
Certain surgical factors may predispose to fracture of the patella. Devascularization of the patella (excessive lateral retinacular release) may compromise the superior-lateral geniculate artery. Component malalignment, oversized femoral component, and use of single central fixation peg may lead to strong patellar strains, and use of bone cement may result in heat necrosis (Figure 4).

Knee Dislocation

The following factors may predispose a patient to postoperative TKA dislocation: implant malpositioning, excessive soft tissue release; extensor mechanism incompetence (i.e., patellectomy); inappropriate selection of the primary implant; infection; late rupture of the PCL or medial collateral ligament; rupture of the polyethylene insert; breakage of the polyethylene post; and neurologic diseases (Figure 5). The PCL-retaining TKA is the design most commonly involved with dislocation.

Heterotopic Ossification

Heterotopic ossification is a rare complication after TKA. The incidence is reported as 15% of all grades, and of those, only 1% are symptomatic. Heterotopic ossification is thought to occur as a result of overexpression of bone morphogenetic protein-4 and prostaglandin-E₂ and can lead to abnormal
formation of mature lamellar bone in soft tissues. When extensive, it may lead to reduced range of motion, localized warmth, mild edema, and erythema.

Risk factors include male gender, old age, history of heterotopic ossification in the ipsilateral or contralateral hip, hypertrophic osteoarthritis, ankylosing spondylitis, diffuse idiopathic skeletal hyperostosis, Paget disease of bone, post-traumatic arthritis, osteonecrosis, and rheumatoid arthritis.

Plain radiographs will not reveal any abnormality for 4 to 6 weeks postoperatively. Bone scan can be positive as early as 3 weeks. Increased bone turnover can be detected as early as 1 week after surgery, with excessive increases in the specific osteoclastic and osteoblastic markers (CTX-1 and P1NP) detected in venous blood. Full maturation of heterotopic bone takes up to 1 year (Figure 6).

Treatment includes physical therapy during maturation, manipulation under general anesthesia, and surgical resection when mature.

Prophylaxis is with radiation therapy and nonsteroidal anti-inflammatory drugs. Radiation therapy should be administered before the fifth postoperative day, optimally within 24 to 48 hours. Radiotherapy given as one dose of 7 to 8 Gy, either preoperatively (<4 hours before) or postoperatively (within 72 hours of surgery) has been advocated. A combination of radiotherapy and indomethacin also may be used.

Radiation therapy administered as prophylaxis to prevent formation of heterotopic ossification after TKA should be administered before the fifth postoperative day.

Aseptic Loosening

Aseptic loosening and infection are the most common indications for revision TKA. Presence of periprosthetic soft tissue lesions has been described interchangeably as adverse local tissue reactions, adverse reactions to metal debris, aseptic lymphocytic vasculitis-associated lesions, metallosis, and pseudotumors. They are more common around metal-on-metal hip arthroplasty, but they also occur in metal-on-polyethylene due to wear of the polyethylene insert. These lesions are noninfectious and nonneoplastic. They result in local tissue destruction and osteolysis and need prompt revision to alternate bearing surfaces (i.e., another type of prosthesis using different materials from the prosthesis that failed).

Radiographic signs of loosening include wide or progressive zone of radiolucency at the interfaces around the prosthetic components, change in position of the prosthetic components, cement fracture or fragmentation, and sclerotic bone reaction around the tip of the tibial prosthetic component (bony pedestal).\(^8\) However, thin radiolucent lines less than 2-mm wide frequently are present, particularly surrounding the tibial component. If these interfaces are stable and do not progress, they usually are considered normal.
Osteolysis commonly involves the tibial component with resultant shift into varus alignment (the tibial shaft points toward the midline relative to the tibial component). Femoral loosening leads to increase in flexion of the component (Figure 7).

Thin, nonprogressive, radiolucent lines less than 2 mm wide about the prosthetic components of a TKA, particularly the tibia, are considered normal.

**Infection**

The incidence of infection is reported as 0.5% to 2% in primary knee arthroplasties and up to 10% in revision arthroplasties.

Infection of knee arthropathies is difficult to distinguish from aseptic loosening. Conventional radiographs may demonstrate extensive, poorly defined radiolucent zones at the interfaces around the prosthetic components and periosteal reaction (Figure 8).

Factors that may predispose a patient to infection of knee arthroplasties include obesity, diabetes, rheumatoid arthritis,
preoperative skin ulcerations, previous surgical (but not arthroscopic) knee procedures, anemia, atrial fibrillation, and psoriasis.

**Other Imaging Modalities**

Nuclear radiology studies may be helpful in the diagnosis of infected TKA.

Three-phase Tc-99m MDP bone scans of infected TKA demonstrate increased uptake on all three phases. Sensitivity is reported to be as high as 95%, but the specificity is low. Osteolysis/aseptic loosening may have the same bone scan findings as infection (Figure 9). Physiologic increased uptake in a TKA can persist for up to 1 year after surgery on the first two phases and indefinitely on the third (skeletal) phase.

Indium-111-labeled leukocytes accumulate in areas of inflammation, infection, postoperative healing wounds, and normal postoperative marrow. Increased uptake around normal asymptomatic implants can be present in about 50% of patients with TKA. Therefore, by itself, an indium-111 leukocyte scan has poor positive predictive value for infection, but it does have high sensitivity of 95% and high negative predictive value of nearly 100%.

**Figure 9.** Aseptic loosening of TKA. Three-phase bone scan of a 72-year-old woman who underwent left TKA 9 years previously. During the past 6 months, she experienced increasing knee pain. This three-phase bone scan demonstrates abnormal activity around the femoral component of the left knee arthroplasty on all 3 phases (circles). The femoral component was grossly loose at surgery without evidence of infection and with negative intraoperative cultures, consistent with aseptic loosening. A: First phase. B: Second phase. C: Third phase.

**Figure 10.** Infection of bilateral TKA. Indium-111 leukocyte scan in a 65-year-old woman with methicillin-susceptible *Staphylococcus aureus* bacteremia and subsequent bilateral prosthetic knee joint infection demonstrates increased uptake in the distal femurs bilaterally (left greater than right).
It is important to compare a positive indium scan with a technetium-99m sulfur colloid marrow scan to improve the accuracy and specificity (Figure 10).

On the technetium sulfur colloid bone marrow scans, sulfur colloid accumulates throughout the reticuloendothelial system, in the bone marrow, and in the liver and the spleen. Hyperplastic/abnormal marrow surrounding joint replacements giving rise to increased indium uptake should have corresponding matching increased uptake on the marrow scan. Infection inhibits or decreases marrow uptake of sulfur colloid and results in less uptake on the marrow scan in areas of periprosthetic infection. Congruent scans carry a low likelihood of infection. Incongruent findings correlate with a high likelihood (>90%) of infection.8

Incongruent indium-III and technetium sulfur colloid scans correlate with a high likelihood (>90%) of TKA infection.

Knee arthrography is relatively quick and inexpensive. It allows real-time dynamic assessment of TKA; however, it is limited in its ability to depict soft tissue pathology (Figure 11).9

Conclusion

This CME activity emphasizes that knowledge of the most common postoperative complications after TKA and their radiographic appearance is crucial for their early detection and timely communication of the findings to the orthopedic surgeon.

References

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1. Which one of the following knee arthroplasties is indicated for a patient with a deficient or absent PCL?
   A. Medial pivot knee
   B. PCL-substituting
   C. PCL-retaining
   D. Varus-valgus constrained
   E. Rotating-hinge

2. All of the following are risk factors for patellar component tilt, patellar subluxation, or patellar dislocation after TKA, except
   A. preoperative valgus deformity
   B. malrotation of the tibial component
   C. deficient PCL
   D. malrotation of the femoral component
   E. lateral retinacular tightness

3. Which of the following is/are predisposing risk factors for postoperative TKA dislocation?
   A. Implant malpositioning
   B. Late rupture of the PCL
   C. Patellectomy
   D. Excessive soft tissue release
   E. All of the above

4. Which one of the following statements regarding three-phase Tc-99m MDP bone scanning after TKA is false?
   A. An infected TKA demonstrates increased uptake on all three phases.
   B. Sensitivity is high.
   C. Aseptic loosening may have the same bone scan findings as infection.
   D. Physiologic increased uptake can persist indefinitely about the knee on the third (skeletal) phase.
   E. Specificity is high.

5. All of the following are risk factors for development of heterotopic ossification about the knee after TKA, except
   A. diffuse idiopathic skeletal hyperostosis
   B. Paget disease of the bone
   C. ankylosing spondylitis
   D. chronic renal disease
   E. rheumatoid arthritis

6. All of the following are radiographic features of loosening of a TKA, except
   A. cement fracture
   B. nonprogressive, thin, radiolucent lines less than 2-mm wide at the interfaces around the prosthetic components
   C. change in position of the prosthetic components
   D. wide or progressive zone of radiolucency at the interfaces around the prosthetic components
   E. sclerotic bone reaction around the tip of the tibial prosthetic component

7. Which one of the following statements concerning infected knee arthroplasties is false?
   A. They often are difficult to distinguish from aseptic loosening on conventional radiographs.
   B. Conventional radiographs may demonstrate extensive, poorly defined radiolucent zones about prosthetic components.
   C. The incidence is higher in primary than in revision arthroplasties.
   D. Risk factors include obesity, diabetes, and preoperative skin ulcerations.
   E. By itself, indium-III leukocyte scanning has a high negative predictive value for infection.

8. Which one of the following is an acceptable prophylactic treatment for prevention of heterotopic ossification about the knee in patients at risk following TKA?
   A. Radiation therapy
   B. IV corticosteroids
   C. High-dose vitamin D
   D. IV platelets
   E. Methotrexate

9. The PCL-substituting TKA is indicated for all of the following conditions, except
   A. previous patellectomy
   B. deficient PCL
   C. absent PCL
   D. acute patellar dislocation
   E. inflammatory arthritis

10. Which one of the following is the most common site of a periprosthetic fracture about a TKA?
    A. Fibular head
    B. Patella
    C. Medial tibial plateau
    D. Lateral tibial plateau
    E. Supracondylar area of the distal femur