American College of Radiology
ACR Appropriateness Criteria®
Acute Trauma to the Knee

Variant 1: **Adult or child 5 years of age or older. Fall or acute twisting trauma to the knee. No focal tenderness, no effusion, able to walk. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography knee	May Be Appropriate	☢
Bone scan with SPECT or SPECT/CT knee	Usually Not Appropriate	☢☢☢
CT knee with IV contrast	Usually Not Appropriate	☢
CT knee without and with IV contrast	Usually Not Appropriate	☢
CT knee without IV contrast	Usually Not Appropriate	☢
MR arthrography knee	Usually Not Appropriate	O
MRA knee without and with IV contrast	Usually Not Appropriate	O
MRA knee without IV contrast	Usually Not Appropriate	O
MRI knee without and with IV contrast	Usually Not Appropriate	O
MRI knee without IV contrast	Usually Not Appropriate	O
US knee	Usually Not Appropriate	O

Variant 2: **Adult or child 5 years of age or older. Fall or acute twisting trauma to the knee. One or more of the following: focal tenderness, effusion, inability to bear weight. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography knee	Usually Appropriate	☢
Bone scan with SPECT or SPECT/CT knee	Usually Not Appropriate	☢☢☢
CT knee with IV contrast	Usually Not Appropriate	☢
CT knee without and with IV contrast	Usually Not Appropriate	☢
CT knee without IV contrast	Usually Not Appropriate	☢
MR arthrography knee	Usually Not Appropriate	O
MRA knee without and with IV contrast	Usually Not Appropriate	O
MRA knee without IV contrast	Usually Not Appropriate	O
MRI knee without and with IV contrast	Usually Not Appropriate	O
MRI knee without IV contrast	Usually Not Appropriate	O
US knee	Usually Not Appropriate	O

Variant 3: **Adult or skeletally mature child. Fall or acute twisting trauma to the knee. No fracture seen on radiographs. Suspect occult fracture or internal derangement. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI knee without IV contrast	Usually Appropriate	O
CT knee without IV contrast	May Be Appropriate	☢
Bone scan with SPECT or SPECT/CT knee	Usually Not Appropriate	☢☢☢
CT knee with IV contrast	Usually Not Appropriate	☢
CT knee without and with IV contrast	Usually Not Appropriate	☢
MR arthrography knee	Usually Not Appropriate	O
MRA knee without and with IV contrast	Usually Not Appropriate	O
MRA knee without IV contrast	Usually Not Appropriate	O
MRI knee without and with IV contrast	Usually Not Appropriate	O
US knee	Usually Not Appropriate	O

Variant 4: **Skeletally immature child. Fall or acute twisting trauma to the knee. No fracture seen on radiographs. Suspect occult fracture or internal derangement. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI knee without IV contrast	Usually Appropriate	O
CT knee without IV contrast	May Be Appropriate	☢
Bone scan with SPECT or SPECT/CT knee	Usually Not Appropriate	☢☢☢
CT knee with IV contrast	Usually Not Appropriate	☢
CT knee without and with IV contrast	Usually Not Appropriate	☢
MR arthrography knee	Usually Not Appropriate	O
MRA knee without and with IV contrast	Usually Not Appropriate	O
MRA knee without IV contrast	Usually Not Appropriate	O
MRI knee without and with IV contrast	Usually Not Appropriate	O
US knee	Usually Not Appropriate	O

Variant 5: **Adult or child 5 years of age or older. Fall or acute twisting trauma to the knee. Tibial plateau fracture on radiographs. Suspect additional bone or soft-tissue injury. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI knee without IV contrast	Usually Appropriate	O
CT knee without IV contrast	Usually Appropriate	☢
Bone scan with SPECT or SPECT/CT knee	Usually Not Appropriate	☢☢☢
CT knee with IV contrast	Usually Not Appropriate	☢
CT knee without and with IV contrast	Usually Not Appropriate	☢
MR arthrography knee	Usually Not Appropriate	O
MRA knee without and with IV contrast	Usually Not Appropriate	O
MRA knee without IV contrast	Usually Not Appropriate	O
MRI knee without and with IV contrast	Usually Not Appropriate	O
US knee	Usually Not Appropriate	O

Variant 6: **Adult or child 5 years of age or older. Acute trauma to the knee. Mechanism unknown. Focal patellar tenderness, effusion, able to walk. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography knee	Usually Appropriate	☢
Bone scan with SPECT or SPECT/CT knee	Usually Not Appropriate	☢☢☢
CT knee with IV contrast	Usually Not Appropriate	☢
CT knee without and with IV contrast	Usually Not Appropriate	☢
CT knee without IV contrast	Usually Not Appropriate	☢
MR arthrography knee	Usually Not Appropriate	O
MRA knee without and with IV contrast	Usually Not Appropriate	O
MRA knee without IV contrast	Usually Not Appropriate	O
MRI knee without and with IV contrast	Usually Not Appropriate	O
MRI knee without IV contrast	Usually Not Appropriate	O
US knee	Usually Not Appropriate	O

Variant 7: **Adult or child 5 years of age or older. Significant trauma to the knee (eg, motor vehicle accident, knee dislocation). Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography knee	Usually Appropriate	☢
CTA lower extremity with IV contrast	Usually Appropriate	☢☢☢
Arteriography lower extremity	May Be Appropriate	☢☢
CT knee with IV contrast	May Be Appropriate (Disagreement)	☢
CT knee without IV contrast	May Be Appropriate	☢
MRA knee without and with IV contrast	May Be Appropriate	O
MRI knee without IV contrast	May Be Appropriate	O
MRA knee without IV contrast	Usually Not Appropriate	O
Bone scan with SPECT or SPECT/CT knee	Usually Not Appropriate	☢☢☢
CT knee without and with IV contrast	Usually Not Appropriate	☢
MR arthrography knee	Usually Not Appropriate	O
MRI knee without and with IV contrast	Usually Not Appropriate	O
US knee	Usually Not Appropriate	O

ACUTE TRAUMA TO THE KNEE

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Summary of Literature Review

Introduction/Background

Acute bone and soft-tissue injuries to the knee may result from low- or high-energy trauma and are commonly seen in emergency departments as well as in outpatient practices [1]. The most common acute knee injuries result from a direct blow, a fall, or a twisting injury [2,3]. The fracture risk increases with age, likely secondary to decreased bone mineral density, increased frequency of blunt injury, and inability to protect the knee during a fall [3]. An estimated 6.6 million knee injuries presented to emergency departments in the United States from 1999 through 2008, for a rate of 2.29 knee injuries per 1,000 population. Prompt and accurate diagnosis facilitates adequate management and may prevent potential complications [1,4].

After thorough history and clinical examination, radiographs are usually the initial imaging modality in the evaluation of the acutely injured knee [1]. Adequate clinical examination and appropriate application of the established decision-making rules can reduce the number of radiographic studies in the setting of acute knee injuries with a potential benefit of reducing health care costs and decreasing radiation exposure to the patient [1,5,6]. Treatment options for acute traumatic knee injuries depend on the severity of injury and patient factors and include conservative or surgical management [1].

Special Imaging Considerations

For the purpose of this document, point-of-care ultrasound (US) is not discussed or listed in the variant tables.

For the purposes of distinguishing between CT and CT angiography (CTA), ACR Appropriateness Criteria topics use the definition in the ACR-NASCI-SIR-SPR Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography (CTA) [7].

> *"CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial or venous enhancement. The resultant volumetric dataset is interpreted using primary transverse reconstructions as well as multiplanar reformations and 3-D renderings."*

All elements are essential: 1) timing, 2) reconstructions/reformats, and 3) 3-D renderings. Standard CTs with contrast also include timing issues and recons/reformats. Only in CTA; however, is 3-D rendering a **required** element. This corresponds to the definitions that the CMS has applied to the Current Procedural Terminology codes.

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Discussion of Procedures by Variant

Variant 1: Adult or child 5 years of age or older. Fall or acute twisting trauma to the knee. No focal tenderness, no effusion, able to walk. Initial imaging.

CT Knee
In the absence of focal tenderness and joint effusion in a patient who is able to walk, CT is not used as the initial imaging study for the evaluation of acute trauma to the knee.

MR Arthrography Knee
MR arthrography is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

MRA Knee
MR angiography (MRA) is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

MRI Knee
MRI is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

Radiography Knee
With no clinical symptoms in the injured knee, including lack of focal tenderness and joint effusion, and with ability to walk, knee radiographs may be indicated if a patient >55 years old per Ottawa rules or >50 years old or <12 years old per Pittsburgh rule criteria [5, 6, 10]. If the patient is between 5 and 12 years, they fall outside the age range for both the Ottawa and Pittsburgh rules and radiographs may be beneficial despite lack of clinical symptoms.

Radiographs are commonly performed in the setting of acute knee injuries but have a low yield for showing fractures. In a retrospective review of 1,967 patients with acute knee injuries by Stiell et al [2], 74.1% of patients had knee radiography, and only 5.2% of these had fractures. Therefore, to avoid a large number of negative radiographic studies, development of the inclusion criteria for obtaining knee radiographs in the setting of the acute trauma was needed.

The two most commonly used clinical decision criteria, the Ottawa Knee Rule and the Pittsburgh Decision Rule, can help to decide when to perform radiographs in acute knee trauma [5,6,8].

Ottawa Knee Rule
The Ottawa Knee Rule [5,6,8] states that patients ≥18 years of age with acute knee pain should have knee radiographs if they meet any of the following criteria:

- Are 55 years of age or older,
- Have palpable tenderness over the head of the fibula,
- Have isolated patellar tenderness,
- Cannot flex the knee to 90°,
- Cannot bear weight immediately following the injury, or
- Cannot walk in the emergency room (after taking 4 steps).

Pittsburgh Decision Rule
The Pittsburgh Decision Rule states that patients with acute knee trauma who are <12 years old or >50 years old should have radiographs as well as patients who cannot take 4 weight-bearing steps in the emergency department [5,6].

In their prospective study in 178 patients with acute knee trauma with the Ottawa rule criteria applied, Jenny et al [8] found a 35% decrease in the number of radiographic examinations with 100% sensitivity for detecting knee fracture. Similarly, Cheung et al [6] found a 23% reduction of knee radiographs in 90 patients if the Ottawa rule criteria were applied, although they did report 1 patient who had a fracture and did not meet any of the clinical criteria, but this fracture was radiographically occult and visible only by MRI.

In their retrospective study on 106 acute knee trauma patients, Konan et al [5] evaluated the role of the Ottawa and Pittsburgh rules to reduce the unnecessary use of radiographs following knee injury. One hundred and one patients (95%) had radiographs of their injured knees. Only 5% of these patients had a fracture on radiographs, all with Ottawa and Pittsburgh knee rules fulfilled. Using the Ottawa rules, 27 radiographic studies (25%) could have been

avoided without missing a fracture. Using the Pittsburgh rules, 32 radiographic studies (30%) could have been avoided. In this study, both the Ottawa and Pittsburgh rules showed high sensitivity in detecting knee fractures [5].

Other clinical decision criteria were tested. In an emergency department, in a study of 242 patients >17 years with isolated knee injuries sustained 24 hours previously, Weber et al [3] were able to exclude clinically significant fractures in patients >18 years who could walk without limping or if there was a twisting injury to the knee and no joint effusion. These clinical decision rules were effective in detecting knee fractures with 100% sensitivity and with sufficient specificity to eliminate 29% of knee radiographs [3].

In their prospective study of 146 patients 3 to 18 years of age with acute trauma to the knee, Moore et al [9] evaluated three criteria including: 1) inability to bear weight, 2) inability to flex the knee to 90°, and 3) presence of bony tenderness. They found a potential 53% reduction in radiographs if applying only the criteria of ability to take 4 weight-bearing steps in the emergency department. Three of their patients negative for criterion 3 were found to have fractures.

It is general agreement that radiographs should be obtained and the clinical decision rule should not be applied for patients with gross deformity [3], a palpable mass [10], a penetrating injury, prosthetic hardware, an unreliable clinical history or physical examination secondary to multiple injuries [3,10], altered mental status (eg, head injury, drug or alcohol use, dementia) [3,10], neuropathy (eg, paraplegia, diabetes) [3,10], or a history suggesting increased risk of fracture. However, in any case scenario, the physician's judgment and common sense should supersede clinical guidelines [3].

For evaluation of the acutely injured knee in patients meeting Ottawa or Pittsburgh rule criteria, a minimum of 2 radiographs (anteroposterior and lateral) of the affected knee should be obtained. The lateral view is obtained with the knee at 25° to 30° of flexion in the lateral decubitus position and should demonstrate the patella in profile. It allows the evaluation for the presence of joint effusion. A cross-table lateral view with a horizontal beam enables visualization of lipohemarthrosis, frequently seen with intra-articular fractures [11]. Additional commonly performed supplemental imaging projections in the acute knee trauma setting include patellofemoral, internal oblique, and external oblique views. The patellofemoral view is typically obtained in suspected patellar fractures and/or subluxation or dislocation [1].

Bone Scan with SPECT or SPECT/CT Knee
Tc-99m bone scan with single-photon emission computed tomography (SPECT)/CT knee is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

US Knee
US is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

Variant 2: Adult or child 5 years of age or older. Fall or acute twisting trauma to the knee. One or more of the following: focal tenderness, effusion, inability to bear weight. Initial imaging.

CT Knee
CT is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

MR Arthrography Knee
MR arthrography is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

MRA Knee
MRA is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

MRI Knee
MRI is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

Radiography Knee
With one or more positive Ottawa rule criteria, including focal tenderness and/or inability to bear weight, radiographs should be the initial imaging modality for the evaluation of acute trauma to the knee [5,6,8].

Bone Scan with SPECT or SPECT/CT Knee
Tc-99m bone scan with SPECT/CT knee is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

US Knee
US is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

Variant 3: Adult or skeletally mature child. Fall or acute twisting trauma to the knee. No fracture seen on radiographs. Suspect occult fracture or internal derangement. Next study.

CT Knee

CT may be performed as the next imaging study for the evaluation of suspected radiographically occult knee fractures.

Several studies reported CT to be superior to knee radiographs in detection and classification of fractures. In a study by Mustonen et al [12], CT showed 100% and radiographs 83% sensitivity in detection of tibial plateau fractures, and CT was superior in further characterization of fracture severity.

In the setting of acute knee trauma, Mui et al [13] reported 80% sensitivity and 98% specificity of the CT examination in detecting bony avulsion fractures and a high negative predictive value for excluding ligamentous injuries, but MRI remained necessary for the preoperative detection of meniscal injury.

Peltola et al [14] compared dual-energy CT examinations with MRI studies as a reference standard in 18 patients with acute knee trauma and reported dual-energy CT had 79% sensitivity and 100% specificity in detecting anterior cruciate ligament (ACL) ruptures [14].

In a study by Heffernan et al [15], 64-channel multidetector CT showed 87.5% to 100% sensitivity and 100% specificity for detection of the ACL tears. As on MRI, secondary signs, such as buckling of the posterior cruciate ligament, were also useful in their diagnosis. In this study, multidetector CT showed a low sensitivity for other soft-tissue injuries at the knee; however, its high specificity indicated that apparent posterior cruciate ligament, meniscal, and collateral ligament tears can reliably be treated as true-positive findings [15].

The dual-energy CT virtual noncalcium technique can subtract calcium from cancellous bone, allowing detection [16-18] and possibly grading of the post-traumatic bone marrow contusions [18].

However, MRI is superior to CT in detection of bone marrow abnormalities and meniscal and ligamentous injuries and may be subsequently performed as clinically indicated.

MR Arthrography Knee

With negative radiographs, MR arthrography is not routinely used as the next imaging study for the evaluation of suspected occult knee fractures or internal derangement.

MRA Knee

With negative radiographs, MRA is not routinely used as the next imaging study for the evaluation of suspected occult knee fractures or internal derangement.

MRI Knee

MRI has many distinct advantages for the evaluation of the injured knee in the setting of negative radiographs.

The majority of patients (93.5%) who present with acute knee injuries in the emergency department sustained soft-tissue injuries rather than osseous injuries [19]. MRI is a proven valuable tool in the treatment decision-making process, allowing earlier surgical intervention by obtaining a more accurate diagnosis [20,21]. Frobell et al [22] reported a low diagnostic benefit of the initial clinical examination in the setting of acute knee trauma with higher-than-suspected incidence of the ACL injuries on MRI. In randomized studies of patients with knee injuries [23,24], MRI findings shortened the diagnostic completion workup, reduced the number of additional diagnostic procedures, and improved quality of life in the first 6 weeks, potentially reducing productivity loss.

A retrospective study by Cecava et al [25] showed that knee radiography is a highly specific screening test for internal derangement in patients <40 years old with acute knee injury. In this patient population, knee effusion >10 mm on lateral radiograph should prompt consideration for the knee MRI examination, which can potentially decrease delayed diagnosis, improve patient outcomes, and decrease disability [25].

Magee et al [26] reported 96% sensitivity and 97% specificity of 3T MRI in the detection of meniscal tears in correlation with arthroscopy. However, a study by Van Dyck et al [21] showed similar high sensitivities and specificities of routine 3T and 1.5T MRI examinations in the evaluation of meniscal and ACL tears with arthroscopic correlation. Routine 3T MRI protocol did not significantly improve accuracy for evaluating the knee menisci and ACL compared with a similar 1.5T MRI protocol.

MRI can diagnose the patterns and severity of bone marrow contusions that frequently have an association with the specific mechanisms of injury and can predict associated soft-tissue injuries [27,28]. In a study by Song et al [28],

in the setting of the acute noncontact ACL injury, both the presence and the severity of lateral bone contusions were associated with high-grade pivot-shift, concomitant lateral meniscal lesions as well as anterolateral ligament abnormality. Klengel et al [29] found that the apparent diffusion coefficient maps are more sensitive than corresponding proton density-weighted fat-saturated turbo spin-echo MRI sequences for detection of bone marrow lesions after knee trauma and allowed detection of significantly more and larger bone marrow lesions. Additionally, apparent diffusion coefficient map evaluation improved diagnostic performance in regions with insufficient spectral fat saturation, such as the patella. Koster et al [30] showed that the presence of a bone contusion on MRI after acute knee trauma is highly predictive of the development of focal osteoarthritis 1 year after trauma.

MRI facilitates diagnosis of the anterolateral ligament injuries that have frequent association with ACL injuries and anterolateral knee instability, of which a minority are associated with Segond fractures [31]. In a study by Kosy et al [32], MRI detected a larger number of anterolateral ligament injuries in association with the ACL injuries within 6 weeks of the acute knee trauma compared with scans performed later, which suggests that some injuries may resolve or become less visible with increased chronicity. MRI is proven helpful in detection and characterization of posterolateral corner injuries, which can be associated with the ACL ruptures and, if missed, may lead to considerable morbidity. In a study by Temponi et al [33], concomitant posterolateral corner injuries and the ACL ruptures were present in 19.7% of patients on MRI studies. Precise location and classification of the ACL tears on the MRI study may help in preoperative planning, in particular with a growing interest in this ligament preservation technique [34].

MRI can change management from surgical to conservative in up to 48% of patients presenting with a locked knee, which is usually an indication for arthroscopic procedure [35,36].

Bone Scan with SPECT or SPECT/CT Knee

Tc-99m bone scan would not be the next best imaging study to evaluate for radiographically occult fractures and/or internal derangement.

Tc-99m-methylene diophosphate bone SPECT/CT scan has been suggested as an alternative to MRI in evaluating suspected bone contusions and meniscal and ACL tears in the setting of acute knee trauma. A SPECT study by Even-Sapir et al [37] with arthroscopic and MRI correlation showed promising results in diagnosis of the ACL and meniscal tears and the associated bone contusions in patients with acute knee trauma. Another study by Siegel et al [38] suggested that the degree of radiotracer uptake in the knee, as determined by SPECT, positively correlates with the severity of pathology seen at arthroscopy. However, a more recent SPECT study with arthroscopic correlation by Wertman et al [39] showed a lower sensitivity, specificity, and accuracy than MRI in evaluating meniscal injuries.

US Knee

US is not used as the next best imaging study to evaluate for radiographically occult fractures and/or internal derangement.

US is an excellent and easily performed imaging study in detection of knee joint effusions. However, because of its technical limitations, US may only evaluate the outer bone surface and has a limited role in detection of the occult knee fractures. Therefore, this imaging modality is not routinely used for the evaluation of suspected occult knee fractures but may detect a lipohemarthrosis, which is typically associated with intra-articular fractures. A comparison of US studies with radiography and CT examinations by Bonnefoy et al [40] serving as the reference standard and using a knee lipohemarthrosis as a criterion, yielded a sensitivity of and specificity of 94% for US detection of acute intra-articular fractures. A recent study by Klos et al [41] showed a higher prevalence of Segond avulsions fractures on US studies than previously reported in literature on the MRI or radiography. The lateral femoral condyle impaction injury was the best variable in predicting the presence of a Segond fracture [41].

US is highly accurate in diagnosis of partial-thickness and full-thickness quadriceps tendon tears, with sensitivity and specificity approaching 100% [42]. However, the utility of US in the evaluation of the knee menisci, cruciate and collateral ligaments, and periarticular soft tissues varies depending on patient factors. In particular, US enables limited visualization of the cruciate ligaments, portions of the menisci, and articular surfaces of the knee joint. In a study by Wang et al [43], the presence of a joint effusion at US in the setting of acute knee trauma showed a 91% positive predictive value for internal derangement. Wareluk et al [44] reported an 85% sensitivity and 86% specificity of the US imaging for detection of meniscal tears, with the specificity highest in recent injuries (<1 month). Alizadeh et al [45] showed comparable sensitivity and specificity of the US and MRI examinations in detection of medial meniscal tears in patients who were ≤30 years old with arthroscopic correlation. A meta-analysis

US study by Dai et al including 551 patients from 7 prospective studies revealed pooled sensitivity of 88% and specificity of 90% in diagnosis of meniscal injuries [46].

Another meta-analysis of 4 US studies including 246 patients revealed pooled sensitivity of 90% and specificity of 97% in the diagnosis of ACL injuries [47]. An US study in correlation with MRI and pivot shift testing suggested a potential utility of US examination in diagnosis of the anterolateral ligament injury [48]. Wang et al [49] found 2-D US a potentially useful tool in diagnosis of posterior cruciate ligament injuries with a posterior cruciate ligament thickness ≥6.5 mm as a recommended diagnostic criterion.

Variant 4: Skeletally immature child. Fall or acute twisting trauma to the knee. No fracture seen on radiographs. Suspect occult fracture or internal derangement. Next study.

CT Knee

With negative radiographs, CT may be performed as the next imaging study for the evaluation of suspected radiographically occult knee fractures [12] and bone marrow contusions [16-18]. CT may diagnose or predict ligamentous injuries [14,15,50,51] and predict meniscal [15,50,51] injuries. However, MRI is superior to CT in evaluation of bone marrow lesions [27-29], meniscal [21,26] and ligamentous [21,31-34] injuries, and may be subsequently performed as clinically indicated.

MR Arthrography Knee

With negative radiographs, MR arthrography is not routinely used as the next imaging study for the evaluation of suspected occult knee fractures or internal derangement.

MRA Knee

With negative radiographs, MRA is not routinely used as the next imaging study for the evaluation of suspected occult knee fractures or internal derangement.

MRI Knee

MRI should be the next imaging modality to evaluate for the presence of radiographically occult fractures and/or internal derangements of the acutely injured knee. With its superb contrast resolution and multiplanar imaging capability, MRI is proven to be a highly accurate imaging modality in the evaluation of bone marrow contusions and occult fractures [27-29] as well as meniscal [21,26] and ligamentous injuries [21,31-34].

Bone Scan with SPECT or SPECT/CT Knee

Tc-99m bone scan with SPECT/CT would not be the next best imaging study to evaluate for radiographically occult fractures and/or internal derangement.

Even-Sapir et al [37] showed promising results of a SPECT study in diagnosis of the ACL and meniscal tears and the associated bone contusions in patients with acute knee trauma with arthroscopic and MRI correlation. However, a more recent SPECT study with arthroscopic correlation by Wertman et al [39] showed a lower sensitivity, specificity, and accuracy than MRI in evaluating meniscal injuries.

US Knee

US would not be the next best imaging study to evaluate for radiographically occult fractures and/or internal derangement of the acutely injured knee. However, US may demonstrate a lipohemarthrosis, indicating the presence of an intra-articular fracture [40]. US is an excellent imaging modality for the diagnosis of quadriceps tendon tears [42] with good performance in the evaluation of the meniscal [44-46] and ligamentous [47-49] injuries. However, the utility of US in the evaluation of the knee menisci, cruciate and collateral ligaments, and periarticular soft tissues varies depending on patient factors.

Variant 5: Adult or child 5 years of age or older. Fall or acute twisting trauma to the knee. Tibial plateau fracture on radiographs. Suspect additional bone or soft-tissue injury. Next study.

CT Knee

In patients with radiographic diagnosis of the tibial plateau fracture, CT is frequently performed for further classification and characterization of the fracture severity [12,52] and may predict or diagnose ligamentous injuries [13-15,50,51] and predict meniscal injuries [15,50]. A study by Spiro et al [50] found that the amount of articular surface depression on CT is a predictor of meniscal and ligamentous injuries and can suggest when an MRI is indicated to confirm or exclude meniscal and ligamentous injuries [50]. In a study by Mustonen et al [12], CT showed 100% sensitivity and radiographs 83% sensitivity in detection of tibial plateau fractures, and CT was superior in further characterization of fracture severity. Chang et al [52] reported that CT-reconstructed images

enhance the morphological subclassification of the medial tibial plateau fractures (Schatzker type IV) with common involvement of posterolateral quadrants. In the setting of acute knee trauma, Mui et al [13] reported 80% sensitivity and 98% specificity of the CT examination in detecting bony avulsion fractures. Tang et al [51] found that lateral tibial plateau depression of >11 mm and its specific part involvement on preoperative CT scans could help predict a higher risk of the lateral meniscus tear and the ACL avulsion fracture.

MR Arthrography Knee
With a radiographic diagnosis of tibial plateau fracture, MR arthrography of the knee is not performed to evaluate for additional bone or soft-tissue injury.

MRA Knee
With a radiographic diagnosis of tibial plateau fracture, MRA of the knee is not performed to evaluate for additional bone or soft-tissue injury.

MRI Knee
With a radiographic diagnosis of tibial plateau fracture, MRI would be the next best imaging modality to evaluate for the presence of additional radiographically occult fractures and/or internal derangements of the acutely injured knee. With its superb contrast resolution and multiplanar imaging capability, MRI is proven to be a highly accurate imaging modality in the evaluation of bone marrow contusions and occult fractures [27-29] as well as meniscal [21,26] and ligamentous injuries [21,31-34].

Bone Scan with SPECT or SPECT/CT Knee
With a radiographic diagnosis of tibial plateau fracture, Tc-99m bone scan with SPECT/CT is not performed as the next best imaging study to evaluate for additional bone or soft-tissue injury.

US Knee
With a radiographic diagnosis of tibial plateau fracture, US is not performed as the next best imaging study to evaluate for additional bone or soft-tissue injury.

Variant 6: Adult or child 5 years of age or older. Acute trauma to the knee. Mechanism unknown. Focal patellar tenderness, effusion, able to walk. Initial Imaging.

CT Knee
CT is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee but is superior to knee radiographs in detection and classification of fractures [12].

MR Arthrography Knee
MR arthrography is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

MRA Knee
MRA is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

MRI Knee
MRI is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee. MRI aids in diagnosis and further characterization of bone and soft-tissue injuries associated with transient lateral dislocation of the patella [53-55].

Radiography Knee
With one or more positive Ottawa rule criteria, including focal patellar tenderness and joint effusion, radiographs should be the initial imaging modality for the evaluation of acute trauma to the knee [5,6,8]. For the evaluation of an acutely injured knee joint in patients with positive Ottawa rule criteria, a minimum of 2 radiographs—anteroposterior and lateral views of the affected knee—should be obtained [11]. Additional patellofemoral view is typically obtained to evaluate for suspected patellar fractures and/or subluxation or dislocation [1].

Bone Scan with SPECT or SPECT/CT Knee
Tc-99m bone scan with SPECT/CT knee is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

US Knee
US is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee.

Variant 7: Adult or child 5 years of age or older. Significant trauma to the knee (eg, motor vehicle accident, knee dislocation). Initial imaging.

Arteriography Lower Extremity
Vascular injury may be found in about 30% of patients following posterior knee dislocation [56]. Injuries of the popliteal artery require prompt surgical intervention to help limb preservation. Associated peroneal and tibial nerve injuries may cause significant morbidity and require an understanding of their pathophysiologic implications to maximize limb functionality [57]. Angiography has been the reference standard in the evaluation of vascular injuries associated with knee dislocations [58]. However, this is an invasive procedure with associated risk, and with the excellent performance of CTA and MRA, it is usually performed in selected cases [58].

CT Knee
CT is not routinely used as the initial imaging study for the evaluation of acute trauma to the knee. CT is superior to knee radiographs in detection and classification of fractures [12]; however, without IV contrast, CT cannot detect vascular injuries.

CTA Lower Extremity
With suspected vascular injuries in the setting of knee dislocation, CTA is frequently used because it is less invasive and has a similarly high accuracy as conventional angiography [58-60].

MR Arthrography Knee
In patients with significant acute knee trauma with suspected or possible dislocation, MR arthrography of the knee is not routinely used as the initial imaging study.

MRA Knee
MRI is an accurate method used in the evaluation of soft-tissue, osseous, and neural injuries after knee dislocation [61]. MRA may be performed simultaneously with MRI for evaluation of internal derangement and vascular injuries with less morbidity compared with conventional angiography [62]. Potter et al [61] reported their experience with popliteal fossa MRA with encouraging results and complete agreement between the MRA and conventional angiography in patients who had both studies. Similarly, in a study by Tocci et al [62], MRA has been shown to be as accurate and useful as conventional angiography in the evaluation of popliteal artery injuries of patients with knee dislocations.

MRI Knee
With its superb contrast resolution and multiplanar imaging capability, MRI is proven to be a highly accurate imaging modality in the evaluation of bone marrow contusions and occult fractures [27-29] as well as meniscal [21,26] and ligamentous injuries [21,31,32]. It can be performed in conjunction with MRA for evaluation of internal derangement and vascular injuries with less morbidity compared with conventional angiography [62].

Radiography Knee
In the setting of significant acute trauma to the knee, radiographs should be the first imaging study. It is general agreement that radiographs should be obtained and the clinical decision rule should not be applied for patients with gross deformity [3], a palpable mass [10], a penetrating injury, prosthetic hardware, an unreliable clinical history or physical examination secondary to multiple injuries [3,10], altered mental status (eg, head injury, drug or alcohol use, dementia) [3,10], neuropathy (eg, paraplegia, diabetes) [3,10], or a history suggesting increased risk of fracture. Additionally, in any case scenario, the physician's judgment and common sense should supersede clinical guidelines [3].

Bone Scan with SPECT or SPECT/CT Knee
In patients with significant acute knee trauma with suspected/possible dislocation, Tc-99m bone scan with SPECT/CT is not routinely used as the initial imaging study.

US Knee
In patients with significant acute knee trauma with suspected or possible dislocation, US is not routinely used as the initial imaging study.

Summary of Recommendations

- **Variant 1:** Knee radiographs may be appropriate for the initial imaging of patients 5 years of age or older for the evaluation of a fall or acute twisting trauma to the knee when there is no focal tenderness, no effusion, and they are able to walk.

- **Variant 2:** Knee radiographs are usually appropriate as the initial imaging study of patients 5 years of age or older for the evaluation of a fall or acute twisting trauma to the knee when at least one of the following is present: focal tenderness, effusion, inability to bear weight.
- **Variant 3:** MRI knee without IV contrast is usually appropriate as the next imaging study, after radiographs did not show fracture, of adults or skeletally mature children, for the evaluation of suspected occult knee fractures or internal derangement after a fall or acute twisting trauma to the knee.
- **Variant 4:** MRI knee without IV contrast is usually appropriate as the next imaging study after radiographs did not show fracture, of skeletally immature children, for the evaluation of suspected occult knee fractures or internal derangement after a fall or acute twisting trauma to the knee.
- **Variant 5:** MRI knee without IV contrast or CT knee without IV contrast is usually appropriate as the next imaging study after radiographic diagnosis of tibial plateau fracture, of patients 5 years of age or older, to evaluate for the suspicion of additional bone or soft-tissue injury after a fall or acute twisting trauma to the knee. These procedures are equivalent alternatives (ie, only 1 procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 6:** Knee radiographs are usually appropriate as the initial imaging study of patients 5 years of age or older for the evaluation of acute trauma to the knee from an unknown mechanism when at least one of the following is present: focal tenderness, effusion, ability to walk.
- **Variant 7:** Knee radiographs or CTA lower extremity with IV contrast is usually appropriate as the initial imaging study, of patients 5 years of age or older, for the evaluation of significant trauma to the knee (eg, motor vehicle accident, knee dislocation). These procedures are complementary (eg, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care). The panel did not agree on recommending CT knee with IV contrast as the initial imaging study of patients 5 years of age or older for the evaluation of significant trauma to the knee. There is insufficient medical literature to conclude whether or not these patients would benefit from CT knee with IV contrast for the evaluation of significant trauma to the knee. CT of the knee with IV contrast in this patient population is controversial but may be appropriate.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

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. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document [63].

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."		

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The 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 examinations 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.