

American College of Radiology ACR Appropriateness Criteria®

Clinical Condition: Acute Trauma to the Knee

Variant 1: Adult or child >1 year old. Fall or twisting injury, no focal tenderness, no effusion; able to walk. First study.

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee	2		☼
MRI knee without IV contrast	2		O
MRI knee without and with IV contrast	1		O
US knee	1		O
MRA knee without and with IV contrast	1		O
MRA knee without IV contrast	1		O
CT knee without IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
CT knee with IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
CT knee without and with IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
Tc-99m bone scan with SPECT lower extremity	1		☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 2: Adult or child >1 year old. Fall or twisting injury, with one or more of the following: focal tenderness, effusion, inability to bear weight. First study.

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee	9		☼
MRI knee without IV contrast	5		O
US knee	2		O
CT knee without IV contrast	2	The RRL for the adult procedure is ☼.	☼☼
Tc-99m bone scan with SPECT lower extremity	2		☼☼☼
MRI knee without and with IV contrast	1		O
MRA knee without and with IV contrast	1		O
MRA knee without IV contrast	1		O
CT knee with IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
CT knee without and with IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: Acute Trauma to the Knee

Variant 3: Adult or child >1 year old. Fall or twisting injury with either no fracture or a Second fracture seen on a radiograph, suspect internal derangement. Next study.

Radiologic Procedure	Rating	Comments	RRL*
MRI knee without IV contrast	9		O
CT knee without IV contrast	5	The RRL for the adult procedure is ☼.	☼☼
US knee	1		O
MRI knee without and with IV contrast	1		O
MRA knee without and with IV contrast	1		O
MRA knee without IV contrast	1		O
CT knee with IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
CT knee without and with IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
Tc-99m bone scan with SPECT lower extremity	1		☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 4: Adult or child >1 year old. Fall or twisting injury with a tibial plateau fracture on a radiograph, with additional bone or soft-tissue injury suspected. Next study.

Radiologic Procedure	Rating	Comments	RRL*
CT knee without IV contrast	9	This procedure may be helpful for treatment planning or prognosis. The RRL for the adult procedure is ☼.	☼☼
MRI knee without IV contrast	7		O
US knee	1		O
MRI knee without and with IV contrast	1		O
MRA knee without and with IV contrast	1		O
MRA knee without IV contrast	1		O
CT knee with IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
CT knee without and with IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
Tc-99m bone scan with SPECT lower extremity	1		☼☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: Acute Trauma to the Knee

Variant 5: Adult or child >1 year old. Injury to knee, mechanism unknown. Focal patellar tenderness, effusion, able to walk.

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee	9	Consider this procedure if it was not previously obtained or if patella views were not included.	☼
MRI knee without IV contrast	5		O
US knee	2		O
CT knee without IV contrast	2	The RRL for the adult procedure is ☼.	☼☼
Tc-99m bone scan with SPECT lower extremity	2		☼☼☼
MRI knee without and with IV contrast	1		O
MRA knee without and with IV contrast	1		O
MRA knee without IV contrast	1		O
CT knee with IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
CT knee without and with IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 6: Adult or child >1 year old. Significant trauma to the knee from motor vehicle accident, suspect knee dislocation.

Radiologic Procedure	Rating	Comments	RRL*
X-ray knee	9	This procedure should be an initial examination to assess overall injury. A normal x-ray does not preclude further imaging workup for vascular or ligament injury.	☼
MRI knee without IV contrast	9	This procedure is necessary to evaluate the extent of damage to ligaments and other support structures.	O
MRA knee without and with IV contrast	7	This procedure should be performed in conjunction with MRI of the knee.	O
Arteriography lower extremity	7	The RRL for the adult procedure is ☼☼.	☼☼☼
CTA lower extremity with IV contrast	7	This procedure should be performed in conjunction with trauma CT imaging. The RRL for the adult procedure is ☼☼☼.	☼☼☼☼
MRA knee without IV contrast	3	This procedure should be performed in conjunction with MRI of knee.	O
US knee	2		O
CT knee without IV contrast	2	The RRL for the adult procedure is ☼.	☼☼
Tc-99m bone scan with SPECT lower extremity	2		☼☼☼
MRI knee without and with IV contrast	1		O
CT knee with IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
CT knee without and with IV contrast	1	The RRL for the adult procedure is ☼.	☼☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

ACUTE TRAUMA TO THE KNEE

Expert Panel on Musculoskeletal Imaging: Michael J. Tuite, MD¹; Mark J. Kransdorf, MD²; Francesca D. Beaman, MD³; Ronald S. Adler, MD, PhD⁴; Behrang Amini, MD, PhD⁵; Marc Appel, MD⁶; Stephanie A. Bernard, MD⁷; Molly E. Dempsey, MD⁸; Ian Blair Fries, MD⁹; Bennett S. Greenspan, MD, MS¹⁰; Bharti Khurana, MD¹¹; Timothy J. Mosher, MD¹²; Eric A. Walker, MD¹³; Robert J. Ward, MD¹⁴; Daniel E. Wessell, MD¹⁵; Barbara N. Weissman, MD.¹⁶

Summary of Literature Review

Introduction/Background

A 2010 report stated that there were over 500,000 visits per year to United States emergency departments because of acute knee trauma [1]. In the pediatric and adolescent population, knee pain is the second most common musculoskeletal complaint and the most common sports-related injury seen in emergency departments [2].

Overview of Imaging Modalities

Radiography

Several studies have found that the knee radiograph is commonly obtained after trauma in the emergency room but has the lowest yield for diagnosing clinically significant fractures [3-5]. Other studies have shown that only about 5% of patients with acute knee trauma have a fracture on radiographs, and that one-fourth of all findings seen on knee radiographs do not correlate with clinical findings [6,7]. Despite this, many acute care clinicians continue to obtain them [8]. The reasons cited include 1) patient expectations, 2) demands of orthopedic consult, 3) lack of confidence in physical examination, and 4) fear of being sued [8].

Clinical decision rules for the acutely injured knee suggest that radiographic examination of the knee following acute injury can be eliminated in many instances by applying specific clinical guidelines [6-10]. Two of the most common clinical decision rules are the Ottawa Knee Rule and the Pittsburgh Decision Rule.

The Ottawa Knee Rule [6] states that patients ≥ 18 years old 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).

Stiell et al [3] applied the rule prospectively in 1,047 adults with acute knee injuries and determined that its application would maintain a 100% sensitivity for fracture while resulting in a 28% relative reduction in the number of radiographs ordered, a decrease from 68.6% to 49.4%. A later study [11] analyzing 1,096 patients found it to be 100% sensitive for identifying knee fractures. The decision rule was interpreted correctly 96% of the time and, when applied, the probability of missing a fracture was zero [11]. A prospective analysis by Jenny et al [12] also showed that it allowed a decrease in the number of radiographs performed after knee trauma by 35%, with a sensitivity of knee fracture detection of 100%. Cheung et al [6] found a similar 23% reduction in 90 patients if the rules were applied, although they did report one patient who had a fracture but did not meet any of the clinical criteria. However, the fracture was radiographically occult and visible only on magnetic resonance

¹Principal Author, University of Wisconsin Hospital, Madison, Wisconsin. ²Panel Chair, Mayo Clinic, Phoenix, Arizona. ³Panel Vice-chair, University of Kentucky, Lexington, Kentucky. ⁴NYU Center for Musculoskeletal Care, New York, New York. ⁵University of Texas MD Anderson Cancer Center, Houston, Texas. ⁶Warwick Valley Orthopedic Surgery, Warwick, New York, American Academy of Orthopaedic Surgeons. ⁷Penn State Milton S. Hershey Medical Center, Hershey, Pennsylvania. ⁸Texas Scottish Rite Hospital, Dallas, Texas. ⁹Bone, Spine and Hand Surgery, Chartered, Brick, NJ, American Academy of Orthopaedic Surgeons. ¹⁰Medical College of Georgia at Georgia Regents University, Augusta, Georgia. ¹¹Brigham & Women's Hospital, Boston, Massachusetts. ¹²Penn State Milton S. Hershey Medical Center, Hershey, Pennsylvania. ¹³Penn State Milton S. Hershey Medical Center, Hershey, Pennsylvania. ¹⁴Tufts Medical Center, Boston, Massachusetts. ¹⁵Mayo Clinic, Jacksonville, Florida. ¹⁶Specialty Chair, Brigham & Women's Hospital, Boston, Massachusetts.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply individual or society endorsement of the final document.

Reprint requests to: publications@acr.org

imaging (MRI). Moore et al [9] applied the rules to 146 children under 18 and found it would have decreased the number of radiographs by 39% while maintaining 100% sensitivity. In a pooled analysis of data from 6 studies, Bachmann et al [13] concluded that a negative result using the Ottawa Knee Rule accurately excluded knee fracture after acute knee injury.

The Pittsburgh Decision Rule says that patients with acute knee trauma who are <12 years old or >50 years old should receive a radiograph, as well as patients who cannot take 4 weight-bearing steps in the emergency department [6]. Seaberg et al [14] reported a 92% sensitivity and 79% specificity for identifying clinically significant fractures. Their study also reported that applying the clinical decision rules could reduce the number of radiographs taken in the emergency room by 78%. Cheung et al [6] also found a potential 52% reduction in the number of radiographs, again with the one false-negative radiographically occult fracture.

Other clinical decision rules have also been investigated. Weber et al [5] concluded that a clinically significant fracture can be excluded in patients older than 18 years who can walk without limping or if there was a twisting injury to the knee and no joint effusion. If an effusion was present on physical examination, the odds of a fracture were 7.5 times greater. Using this clinical decision rule, the sensitivity for detecting a knee fracture was 100%, and specificity was sufficient to eliminate the need for 29% of knee radiographs ordered in the emergency room. Moore et al [9] in 146 patients <18 years old found a potential 53% reduction in radiographs if applying only the criteria of ability to take 4 weight-bearing steps in the emergency department.

A meta-analysis to determine the role of radiography in evaluating knee fractures concluded that among the 5 decision rules evaluated, the Ottawa Knee Rule had the strongest supporting evidence [15]. Another study [16] compared the implementation of the Ottawa Knee Rule by triage nurses and emergency medicine physicians. No fracture was missed by either group, but triage nurses were found to order 3.6 times more radiographs than emergency physicians, maintaining sensitivity at the expense of specificity and cost savings [16].

The mechanism of injury as determined by the history and physical examination can be helpful when deciding if a decision rule should be applied. The most common mechanisms for knee injury are a direct blow, a fall, or a twisting injury [4,5]. Twisting injuries are responsible for three-fourths of all knee injuries; however, 86% of all knee fractures result from blunt trauma [4,5]. The risk of fracture also increases with age; fracture is 4 times more likely in patients >50 years old, presumably secondary to osteoporosis, increased frequency of blunt injury, and inability to protect the knee during a fall [5]. Conversely, absence of immediate swelling, ecchymosis, effusion, deformity, increased warmth, and abrasion/laceration is a significant predictor of a normal radiograph [5,11].

Clinicians should be cautious relying on a nonsystematic clinical examination for diagnosing certain knee injuries, however. Neubauer et al [17] reported that the correct diagnosis of bilateral quadriceps tendon rupture was established in only 61% (17/28) of cases by history and clinical examination alone. Weber et al [5] reported that fractures missed on clinical examination included fractures of the patella, tibial spine, and fibular head.

Magnetic Resonance Imaging

In addition to clinically significant fractures, other injuries must be considered in patients with acute knee pain. Most patients (93.5%) who present with acute knee injuries in the emergency room have soft-tissue rather than osseous injuries [18]. MRI is a valuable tool in the decision-making process, altering the treatment plan and allowing earlier surgical intervention by obtaining a more accurate diagnosis [19,20]. Frobell et al [21] showed that the first clinical examination after acute knee trauma has a low diagnostic value, and that the incidence of anterior cruciate ligament (ACL) injuries on MRI is higher than initially suspected. In randomized studies of patients with knee injuries [22,23], MRI findings have been shown to shorten the time to completion of diagnostic workup, reduce the number of additional diagnostic procedures, improve quality of life in the first 6 weeks, and potentially reduce costs associated with lost productivity. Koster et al [24] showed that the presence of a bone contusion on MRI after acute trauma is highly predictive of the development of focal osteoarthritis 1 year after trauma. Although a locked knee has been described as an indication to go directly to arthroscopy, MRI can change management from surgical to conservative in up to 48% of patients [25,26]. It should be noted that MRI should be read with caution in trauma patients without mechanical signs who have osteoarthritis [27].

Computed Tomography

Computed tomography (CT) with 3-D reconstruction has been compared to knee radiographs and shown to be more sensitive for fracture, 100% versus 83% for radiographs, and to reflect the severity of tibial plateau fractures more accurately [28]. In severely injured patients, diagnostically sufficient radiographs are sometimes difficult to obtain, and therefore a negative radiograph is not reliable in ruling out a fracture [28]. In these patients,

multidetector CT is a fast and accurate examination for evaluating tibial plateau fractures and other complex knee injuries [28,29]. Mui et al [30] concluded that in the acute setting, CT offers 80% sensitivity and 98% specificity for depicting osseous avulsions and a high negative predictive value for excluding ligament injury. Spiro et al [31] found that the amount of articular surface depression on CT is a predictor of meniscus and ligament injuries and can identify when an MRI is indicated.

Dual-energy CT has recently shown that it can detect post-traumatic bone marrow lesions or bone contusions [32,33]. Dual-energy CT may be more useful than single-energy CT in assessing knee trauma because it can not only show subtle fractures, but it can also demonstrate bone contusions that are markers of meniscus and ligament injuries [28].

Single Photon Emission Computed Tomography

Single photon emission computed tomography (SPECT) has been proposed for diagnosing meniscus injuries [34-36]. A specific crescentic pattern of uptake on the transaxial view has been described as having a sensitivity of 77% and specificity of 74%. With the additional criterion of increased equilibrium activity in the adjacent femoral condyles, these values increase to 90% and 84%, respectively [34]. Considerable concordance has been shown between SPECT results and those of other modalities for assessing meniscal tears and the bone contusions from an ACL tear in acute knee trauma [36,37].

Ultrasound

Sonography has been reported to be 91% sensitive and 100% specific for diagnosing an acute ACL tear within 10 weeks of an acute hemarthrosis when there is no prior trauma and no bone abnormalities [38]. Furthermore, a comparison of sonography and radiography using lipohemarthrosis as a criterion of acute intra-articular fracture yielded a sensitivity and specificity of 94% for sonographic detection of such fractures [39]. Wang et al [40] showed that the presence of an effusion at sonography in the acutely injured knee has a 91% positive predictive value for internal derangement. Wareluk et al [41] reported an 85% sensitivity and 86% specificity for meniscal tears, with the specificity highest in recent injuries (<1 month). However, intra-articular knee sonography should only be performed and interpreted by personnel with the appropriate expertise in its application.

Discussion of Imaging Modalities by Variant

Variants 1 and 2: Adult or child >1 year old. Fall or twisting injury. First study.

Clinical decision rules, such as the Ottawa Knee Rule or the Pittsburgh Decision Rule described above, are well-validated and have been shown to reduce the number of radiographs obtained for acute knee trauma while still identifying almost all patients who have a fracture. It is generally agreed that radiographs should be obtained and the clinical decision rule should not be applied for patients with gross deformity [5], a palpable mass [11], a penetrating injury, prosthetic hardware, an unreliable clinical history or physical examination secondary to multiple injuries [5,11], altered mental status (eg, head injury, drug or alcohol use, dementia) [5,11], neuropathy (eg, paraplegia, diabetes) [5,11], or a history suggesting increased risk of fracture. The physician's judgment and common sense, however, should supersede clinical guidelines [5].

Variant 3: Adult or child >1 year old. Fall or twisting injury with either no fracture or a Second fracture seen on a radiograph, suspect internal derangement. Next study.

MRI is considered the optimal imaging modality for identifying meniscal, ligament, chondral, and nondisplaced bone injuries around the knee [42,43]. Numerous studies have shown that MRI has a high diagnostic accuracy in identifying traumatic intra-articular knee lesions [44-46]. This is particularly true when strict diagnostic criteria are used [44], and this applies to both spin-echo imaging and fast spin-echo imaging [44] as well as imaging at both low and high field strength [45,46]. Characteristic imaging patterns on MRI, including specific patterns of bone marrow edema and osteochondral injuries, help make MRI highly accurate for even subtle ligament and meniscal injuries [47].

Variant 4: Adult or child >1 year old. Fall or twisting injury with a tibial plateau fracture on a radiograph, with additional bone or soft-tissue injury suspected. Next study.

Some tibial plateau fractures can be adequately assessed and a treatment decision made using radiographs only [48]. For more complex fractures, CT and MRI are helpful for complete injury assessment and for presurgical planning [49,50]. The advantage of CT is that it shows cortical bone detail well, is easier to obtain if a CT scanner is near the emergency department, has a shorter total scan time (important in severely injured patients), and has a lower cost. The advantage of MRI is that it can demonstrate soft tissue and bone marrow injuries while adequately

demonstrating many cortical bone fractures. Soft-tissue injuries are common in many patients with knee fractures [51,52]. Mustonen et al [52] reported unstable meniscal tears in 36% of patients with tibial plateau fractures. Stannard et al [51] found a meniscus tear in 49% and at least one ligament tear in 71%, of patients with a tibial plateau fracture.

Variant 5: Adult or child >1 year old. Injury to knee, mechanism unknown. Focal patellar tenderness, effusion, able to walk.

Patellar pain after trauma can be from several causes, including patellar fracture and transient patellar dislocation [53,54]. For patellar fractures, radiographs should include a patellar view such as a sunrise view in addition to anterior posterior and lateral radiographs [55].

Transient patellar dislocation is unsuspected clinically in 45%–73% of patients with evidence of dislocation subsequently seen on MRI [56,57]. Radiographs may demonstrate a fracture of the medial patella or lateral trochlear and can also show anatomic features that predispose to dislocation such as a decreased sulcus angle, patella alta, patellar tilt, or patellar subluxation [58]. MRI is more sensitive than radiographs for imaging findings of lateral patellar dislocation, including injury to the medial patellofemoral ligament, bone contusions, and osteochondral injuries [54,59].

Variant 6: Adult or child >1 year old. Significant trauma to knee from motor vehicle accident, suspect knee dislocation.

Dislocation of the knee is uncommon, representing about 0.1% of orthopedic injuries [60]. The injury typically results from a motor-vehicle accident, but can also occur from contact sports, a vehicle striking a pedestrian, falls, or even a spontaneous dislocation in morbidly obese individuals [60]. In 14%–44% of patients the dislocation is part of multiple traumatic injuries [60]. This injury, which may reduce spontaneously, constitutes a true orthopedic emergency because of possible nerve or arterial damage. Vascular injury may be found in about 30% of patients following posterior knee dislocation [61]. Physical signs of clinically significant vascular injury are the absence of pulses, ischemia, active bleeding, and bruit/thrill. Although angiography is considered the gold standard for assessing for vascular injury, there is some debate whether it should be obtained in all knee dislocation patients or be used selectively [60]. Computed tomography angiography (CTA) is increasingly being used because it is less invasive, has a similar high accuracy, and involves a lower radiation dose [60,62,63].

MR angiography (MRA) has also been shown to be an accurate technique for assessing for vascular injury after knee dislocation [61,64,65]. Some authors recommend MRA because the patient can also have a diagnostic knee MR examination at the same time to assess for the extent of ligament injury. Potter et al [66] found excellent correlation between MRI findings and surgical findings in patients with knee dislocation. Furthermore, these authors reported 100% correlation between MRA findings and conventional angiography findings in multiple-ligament injured knees, including knee dislocations [66].

Summary of Recommendations

Clinical decision rules for evaluating the acutely injured knee have been studied by various investigators who determined that their application can considerably reduce the number of radiographs ordered without missing a clinically significant fracture. Although different parameters and definitions were used for the various decision rules, there were sufficient similarities between the investigations to allow usable conclusions to be drawn.

In patients of any age except for infants, the clinical parameters used for *not requiring* radiographs following knee trauma are as follows:

- Patient is able to walk without a limp [6]
- Patient had a twisting injury, and there is no effusion [4]

The clinical parameters for *ordering* knee radiographs in this population following trauma are as follows:

- Joint effusion within 24 hours of a direct blow or fall [4]
- Palpable tenderness over the fibular head or patella [6]
- Inability to walk (4 steps) or bear weight immediately or in the emergency room [6] or within a week of the trauma [67]
- Inability to flex the knee to 90° [6]
- Altered mental status [5,13]

In general, these studies excluded patients with superficial skin injuries, gross deformity, a palpable mass, a penetrating injury, prosthetic hardware, altered consciousness (from alcohol and/or drug use), multiple injuries, decreased limb sensation, or a history indicating an elevated risk of fracture. They also excluded pregnant patients, patients returning for reassessment, and patients whose injury occurred more than 7 days prior to initial evaluation [4,11].

Soft-tissue injuries (meniscal injuries, chondral surface injuries, and ligamentous disruption) are best evaluated by MRI [18,28,51]. Although the lateral patellar dislocation may be reduced at the time of presentation in the emergency room, characteristic findings on MRI, including specific bone marrow edema patterns and osteochondral defects [47], can allow accurate diagnosis.

Knee dislocation, even if spontaneously reduced, constitutes a potential threat to the popliteal nerve or artery. Studies have suggested that the isolated presence of abnormal pedal pulses on initial examination following knee dislocation is not sensitive enough to detect a vascular injury that necessitates surgery, and that the workup should include angiography [60,61]. One study [66] has shown a 100% correlation between MRA findings and conventional angiography findings in multiple-ligament injured knees, including knee dislocations. An MRI should also be performed to identify ligamentous injuries and associated pathology dislocation [61,64,65].

Summary of Evidence

Of the 67 references cited in the *ACR Appropriateness Criteria® Acute Trauma to the Knee* document, all of them are categorized as diagnostic references including 2 well-designed studies, 12 good quality studies, and 16 quality studies that may have design limitations. There are 37 references that may not be useful as primary evidence.

The 67 references cited in the *ACR Appropriateness Criteria® Acute Trauma to the Knee* document were published between 1993–2013.

While there are references that report on studies with design limitations, 14 well-designed or good quality studies provide good evidence.

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, both because of 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 to 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.

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
○	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”.

Supporting Documents

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

References

1. Niska R, Bhuiya F, Xu J. National Hospital Ambulatory Medical Care Survey: 2007 emergency department summary. *Natl Health Stat Report*. 2010(26):1-31.
2. Kluchurosky L. Pediatric & Adolescent Sports Injuries: Recognition and Appropriate Care. Nationwide Children's Hospital Sports Medicine Department. 2007.
3. Stiell IG, Greenberg GH, Wells GA, et al. Derivation of a decision rule for the use of radiography in acute knee injuries. *Ann Emerg Med*. 1995;26(4):405-413.
4. Stiell IG, Wells GA, McDowell I, et al. Use of radiography in acute knee injuries: need for clinical decision rules. *Acad Emerg Med*. 1995;2(11):966-973.
5. Weber JE, Jackson RE, Peacock WF, Swor RA, Carley R, Larkin GL. Clinical decision rules discriminate between fractures and nonfractures in acute isolated knee trauma. *Ann Emerg Med*. 1995;26(4):429-433.
6. Cheung TC, Tank Y, Breederveld RS, Tuinebreijer WE, de Lange-de Klerk ES, Derksen RJ. Diagnostic accuracy and reproducibility of the Ottawa Knee Rule vs the Pittsburgh Decision Rule. *Am J Emerg Med*. 2013;31(4):641-645.
7. Teh J, Kambouroglou G, Newton J. Investigation of acute knee injury. *Bmj*. 2012;344:e3167.
8. Beutel BG, Trehan SK, Shalvoy RM, Mello MJ. The Ottawa knee rule: examining use in an academic emergency department. *West J Emerg Med*. 2012;13(4):366-372.
9. Moore BR, Hampers LC, Clark KD. Performance of a decision rule for radiographs of pediatric knee injuries. *J Emerg Med*. 2005;28(3):257-261.
10. Yao K, Haque T. The Ottawa knee rules - a useful clinical decision tool. *Aust Fam Physician*. 2012;41(4):223-224.
11. Stiell IG, Greenberg GH, Wells GA, et al. Prospective validation of a decision rule for the use of radiography in acute knee injuries. *Jama*. 1996;275(8):611-615.
12. Jenny JY, Boeri C, El Amrani H, et al. Should plain X-rays be routinely performed after blunt knee trauma? A prospective analysis. *J Trauma*. 2005;58(6):1179-1182.
13. Bachmann LM, Haberzeth S, Steurer J, ter Riet G. The accuracy of the Ottawa knee rule to rule out knee fractures: a systematic review. *Ann Intern Med*. 2004;140(2):121-124.
14. Seaberg DC, Jackson R. Clinical decision rule for knee radiographs. *Am J Emerg Med*. 1994;12(5):541-543.
15. Jackson JL, O'Malley PG, Kroenke K. Evaluation of acute knee pain in primary care. *Ann Intern Med*. 2003;139(7):575-588.
16. Matteucci MJ, Roos JA. Ottawa Knee Rule: a comparison of physician and triage-nurse utilization of a decision rule for knee injury radiography. *J Emerg Med*. 2003;24(2):147-150.
17. Neubauer T, Wagner M, Potschka T, Riedl M. Bilateral, simultaneous rupture of the quadriceps tendon: a diagnostic pitfall? Report of three cases and meta-analysis of the literature. *Knee Surg Sports Traumatol Arthrosc*. 2007;15(1):43-53.
18. Blum MR, Goldstein LB. Practical Pain Management. Need for More Accurate ER Diagnoses of ACL Injuries. Available at: <http://www.practicalpainmanagement.com/pain/acute/sports-overuse/need-more-accurate-er-diagnoses-acl-injuries>. Accessed December 17, 2013.
19. Griffin JW, Miller MD. MRI of the knee with arthroscopic correlation. *Clin Sports Med*. 2013;32(3):507-523.
20. Van Dyck P, Vanhoenacker FM, Lambrecht V, et al. Prospective comparison of 1.5 and 3.0-T MRI for evaluating the knee menisci and ACL. *J Bone Joint Surg Am*. 2013;95(10):916-924.
21. Frobell RB, Lohmander LS, Roos HP. Acute rotational trauma to the knee: poor agreement between clinical assessment and magnetic resonance imaging findings. *Scand J Med Sci Sports*. 2007;17(2):109-114.
22. Nikken JJ, Oei EH, Ginai AZ, et al. Acute peripheral joint injury: cost and effectiveness of low-field-strength MR imaging--results of randomized controlled trial. *Radiology*. 2005;236(3):958-967.
23. Oei EH, Nikken JJ, Ginai AZ, et al. Costs and effectiveness of a brief MRI examination of patients with acute knee injury. *Eur Radiol*. 2009;19(2):409-418.
24. Koster IM, Oei EH, Hensen JH, et al. Predictive factors for new onset or progression of knee osteoarthritis one year after trauma: MRI follow-up in general practice. *Eur Radiol*. 2011;21(7):1509-1516.
25. Helmark IC, Neergaard K, Krogsaard MR. Traumatic knee extension deficit (the locked knee): can MRI reduce the need for arthroscopy? *Knee Surg Sports Traumatol Arthrosc*. 2007;15(7):863-868.

26. McNally EG, Nasser KN, Dawson S, Goh LA. Role of magnetic resonance imaging in the clinical management of the acutely locked knee. *Skeletal Radiol.* 2002;31(10):570-573.
27. Bhattacharyya T, Gale D, Dewire P, et al. The clinical importance of meniscal tears demonstrated by magnetic resonance imaging in osteoarthritis of the knee. *J Bone Joint Surg Am.* 2003;85-A(1):4-9.
28. Mustonen AO, Koskinen SK, Kiuru MJ. Acute knee trauma: analysis of multidetector computed tomography findings and comparison with conventional radiography. *Acta Radiol.* 2005;46(8):866-874.
29. Brunner A, Horisberger M, Ulmar B, Hoffmann A, Babst R. Classification systems for tibial plateau fractures; does computed tomography scanning improve their reliability? *Injury.* 2010;41(2):173-178.
30. Mui LW, Engelsohn E, Umans H. Comparison of CT and MRI in patients with tibial plateau fracture: can CT findings predict ligament tear or meniscal injury? *Skeletal Radiol.* 2007;36(2):145-151.
31. Spiro AS, Regier M, Novo de Oliveira A, et al. The degree of articular depression as a predictor of soft-tissue injuries in tibial plateau fracture. *Knee Surg Sports Traumatol Arthrosc.* 2013;21(3):564-570.
32. Pache G, Bulla S, Baumann T, et al. Dose reduction does not affect detection of bone marrow lesions with dual-energy CT virtual noncalcium technique. *Acad Radiol.* 2012;19(12):1539-1545.
33. Pache G, Krauss B, Strohm P, et al. Dual-energy CT virtual noncalcium technique: detecting posttraumatic bone marrow lesions--feasibility study. *Radiology.* 2010;256(2):617-624.
34. Grevitt MP, Taylor M, Churchill M, Allen P, Ryan PJ, Fogelman I. SPECT imaging in the diagnosis of meniscal tears. *J R Soc Med.* 1993;86(11):639-641.
35. Ryan PJ, Reddy K, Fleetcroft J. A prospective comparison of clinical examination, MRI, bone SPECT, and arthroscopy to detect meniscal tears. *Clin Nucl Med.* 1998;23(12):803-806.
36. Siegel Y, Golan H, Thein R. ^{99m}Tc-methylene diphosphonate single photon emission tomography of the knees: intensity of uptake and its correlation with arthroscopic findings. *Nucl Med Commun.* 2006;27(9):689-693.
37. Even-Sapir E, Arbel R, Lerman H, Flusser G, Livshitz G, Halperin N. Bone injury associated with anterior cruciate ligament and meniscal tears: assessment with bone single photon emission computed tomography. *Invest Radiol.* 2002;37(9):521-527.
38. Ptaznik R, Feller J, Bartlett J, Fitt G, Mitchell A, Hennessy O. The value of sonography in the diagnosis of traumatic rupture of the anterior cruciate ligament of the knee. *AJR Am J Roentgenol.* 1995;164(6):1461-1463.
39. Bonnefoy O, Diris B, Moinard M, Aunoble S, Diard F, Hauger O. Acute knee trauma: role of ultrasound. *Eur Radiol.* 2006;16(11):2542-2548.
40. Wang CY, Wang HK, Hsu CY, Shieh JY, Wang TG, Jiang CC. Role of sonographic examination in traumatic knee internal derangement. *Arch Phys Med Rehabil.* 2007;88(8):984-987.
41. Wareluk P, Szopinski KT. Value of modern sonography in the assessment of meniscal lesions. *Eur J Radiol.* 2012;81(9):2366-2369.
42. Hayes CW, Coggins CA. Sports-related injuries of the knee: an approach to MRI interpretation. *Clin Sports Med.* 2006;25(4):659-679.
43. Sanders TG, Miller MD. A systematic approach to magnetic resonance imaging interpretation of sports medicine injuries of the knee. *Am J Sports Med.* 2005;33(1):131-148.
44. De Smet AA, Tuite MJ. Use of the "two-slice-touch" rule for the MRI diagnosis of meniscal tears. *AJR Am J Roentgenol.* 2006;187(4):911-914.
45. Magee T, Williams D. 3.0-T MRI of meniscal tears. *AJR Am J Roentgenol.* 2006;187(2):371-375.
46. Oei EH, Nikken JJ, Verstijnen AC, Ginai AZ, Myriam Hunink MG. MR imaging of the menisci and cruciate ligaments: a systematic review. *Radiology.* 2003;226(3):837-848.
47. Sanders TG, Paruchuri NB, Zlatkin MB. MRI of osteochondral defects of the lateral femoral condyle: incidence and pattern of injury after transient lateral dislocation of the patella. *AJR Am J Roentgenol.* 2006;187(5):1332-1337.
48. te Stroet MA, Holla M, Biert J, van Kampen A. The value of a CT scan compared to plain radiographs for the classification and treatment plan in tibial plateau fractures. *Emerg Radiol.* 2011;18(4):279-283.
49. Markhardt BK, Gross JM, Monu JU. Schatzker classification of tibial plateau fractures: use of CT and MR imaging improves assessment. *Radiographics.* 2009;29(2):585-597.
50. Yang G, Zhai Q, Zhu Y, Sun H, Putnis S, Luo C. The incidence of posterior tibial plateau fracture: an investigation of 525 fractures by using a CT-based classification system. *Arch Orthop Trauma Surg.* 2013;133(7):929-934.

51. Stannard JP, Lopez R, Volgas D. Soft tissue injury of the knee after tibial plateau fractures. *J Knee Surg.* 2010;23(4):187-192.
52. Mustonen AO, Koivikko MP, Lindahl J, Koskinen SK. MRI of acute meniscal injury associated with tibial plateau fractures: prevalence, type, and location. *AJR Am J Roentgenol.* 2008;191(4):1002-1009.
53. Lazaro LE, Wellman DS, Sauro G, et al. Outcomes after operative fixation of complete articular patellar fractures: assessment of functional impairment. *J Bone Joint Surg Am.* 2013;95(14):e96 91-98.
54. Paakkala A, Sillanpaa P, Huhtala H, Paakkala T, Maenpaa H. Bone bruise in acute traumatic patellar dislocation: volumetric magnetic resonance imaging analysis with follow-up mean of 12 months. *Skeletal Radiol.* 2010;39(7):675-682.
55. Scolaro J, Bernstein J, Ahn J. Patellar fractures. *Clin Orthop Relat Res.* 2011;469(4):1213-1215.
56. Kirsch MD, Fitzgerald SW, Friedman H, Rogers LF. Transient lateral patellar dislocation: diagnosis with MR imaging. *AJR Am J Roentgenol.* 1993;161(1):109-113.
57. Lance E, Deutsch AL, Mink JH. Prior lateral patellar dislocation: MR imaging findings. *Radiology.* 1993;189(3):905-907.
58. Colvin AC, West RV. Patellar instability. *J Bone Joint Surg Am.* 2008;90(12):2751-2762.
59. Elias DA, White LM, Fithian DC. Acute lateral patellar dislocation at MR imaging: injury patterns of medial patellar soft-tissue restraints and osteochondral injuries of the inferomedial patella. *Radiology.* 2002;225(3):736-743.
60. Howells NR, Brunton LR, Robinson J, Porteus AJ, Eldridge JD, Murray JR. Acute knee dislocation: an evidence based approach to the management of the multiligament injured knee. *Injury.* 2011;42(11):1198-1204.
61. Boisrenoult P, Lustig S, Bonneville P, et al. Vascular lesions associated with bicruciate and knee dislocation ligamentous injury. *Orthop Traumatol Surg Res.* 2009;95(8):621-626.
62. Fleiter TR, Mervis S. The role of 3D-CTA in the assessment of peripheral vascular lesions in trauma patients. *Eur J Radiol.* 2007;64(1):92-102.
63. Rieger M, Mallouhi A, Tauscher T, Lutz M, Jaschke WR. Traumatic arterial injuries of the extremities: initial evaluation with MDCT angiography. *AJR Am J Roentgenol.* 2006;186(3):656-664.
64. Johnson ME, Foster L, DeLee JC. Neurologic and vascular injuries associated with knee ligament injuries. *Am J Sports Med.* 2008;36(12):2448-2462.
65. Tocci SL, Heard WM, Fadale PD, Brody JM, Born C. Magnetic resonance angiography for the evaluation of vascular injury in knee dislocations. *J Knee Surg.* 2010;23(4):201-207.
66. Potter HG, Weinstein M, Allen AA, Wickiewicz TL, Helfet DL. Magnetic resonance imaging of the multiple-ligament injured knee. *J Orthop Trauma.* 2002;16(5):330-339.
67. Verma A, Su A, Golin AM, O'Marrah B, Amorosa JK. A screening method for knee trauma. *Acad Radiol.* 2001;8(5):392-397.

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.