

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

**Clinical Condition:** Stress/Insufficiency Fracture, Including Sacrum, Excluding Other Vertebrae

**Variant 1:** Suspect stress/insufficiency fracture. First imaging modality.

Radiologic Procedure	Rating	Comments	RRL*
X-ray area of interest	9	Radiograph is a required first step before consideration of other imaging.	NS
MRI area of interest without contrast	1		None
NUC Tc-99m bone scan with SPECT area of interest	1		Med
CT area of interest without contrast	1		NS
<b>Rating Scale:</b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

**Variant 2:** Suspect stress fracture in patient with need to know diagnosis, not hip or sacrum. Radiographs normal.

Radiologic Procedure	Rating	Comments	RRL*
X-ray area of interest repeat in 10-14 days	9	Many patients will recover in the interim and not return.	NS
MRI area of interest without contrast	9	In this clinical situation, many clinicians would wait until repeat radiograph is negative before going to MR; with an anxious patient or clinician, or repeated negative radiograph, MR is the favored next imaging modality.	None
NUC Tc-99m bone scan with SPECT area of interest	1	If the patient or clinician is too anxious to wait for repeat radiographs, could do MR or bone scan (but not both); panel prefers MR since it is usually more specific than bone scan.	Med
CT area of interest without contrast	1	Not indicated.	NS
<b>Rating Scale:</b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

**Variant 3:** Suspect stress fracture, not hip or sacrum. Radiographs normal. Bone scan positive and nonspecific.

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest without contrast	9		None
X-ray area of interest repeat in 10-14 days	7	For confirmation or question of complication.	NS
CT area of interest without contrast	5	If MRI contraindicated.	NS
<b>Rating Scale:</b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

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

**Clinical Condition:****Stress/Insufficiency Fracture, Including Sacrum, Excluding Other Vertebrae****Variant 4:****Suspect stress fracture in otherwise normal patient. Radiographs and bone scan or MRI normal.**

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest without contrast	2	Not indicated if radiographs and MRI were normal; but if the studies were radiographs and bone scan that were normal and there is persistent pain, the clinician might re-examine the diagnosis and consider MRI, looking for soft-tissue injury.	None
X-ray area of interest repeat in 10-14 days	1	Not necessary. No further imaging is warranted.	NS
NUC Tc-99m bone scan with SPECT area of interest	1		Med
CT area of interest without contrast	1		NS
<b>Rating Scale:</b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

**Variant 5:****Clinical differential fracture versus metastasis in long bone. Radiographs normal, bone scan hot but nonspecific.**

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest without contrast	9		None
X-ray area of interest repeat in 10-14 days	1	Too anxiety producing. An occult metastasis is unlikely to appear on radiographs in this period.	NS
CT area of interest without contrast	1		NS
<b>Rating Scale:</b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

**Variant 6:****Clinical differential insufficiency fracture versus metastasis in sacrum. Radiographs normal, bone scan hot but nonspecific.**

Radiologic Procedure	Rating	Comments	RRL*
CT sacrum without contrast	8	First choice. Definitive for diagnosis of fracture.	Med
MRI sacrum without contrast	6	Alternative choice may show other cause for pain or the fracture.	None
X-ray sacrum repeat in 10-14 days	1		Low
<b>Rating Scale:</b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

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

**Clinical Condition:****Stress/Insufficiency Fracture, Including Sacrum, Excluding Other Vertebrae****Variant 7:****Suspect insufficiency fracture in sacrum/pelvis; elderly patient. Radiographs normal. Bone scan hot in linear pattern typical for fracture.**

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest without contrast	6	For confirmation.	None
CT area of interest without contrast	4	For confirmation.	NS
X-ray area of interest repeat in 10-14 days	1		NS
<b>Rating Scale:</b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

**Variant 8:****Suspect insufficiency fracture in osteoporotic patient or patient on long-term corticosteroid therapy, not hip. Radiographs normal.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray area of interest repeat in 10-14 days	9	Panel agrees one of these three exams should be done. The clinical condition and location will dictate which. If the diagnosis is not urgent, repeat radiographs may be all that is necessary. If there is greater urgency, the panel favors MRI over bone scan because bone scans can be falsely negative in this patient population.	NS
MRI area of interest without contrast	9	Panel agrees one of these three exams should be done. The clinical condition and location will dictate which. If the diagnosis is not urgent, repeat radiographs may be all that is necessary. If there is greater urgency, the panel favors MRI over bone scan because bone scans can be falsely negative in this patient population.	None
NUC Tc-99m bone scan with SPECT area of interest	9	Panel agrees one of these three exams should be done. The clinical condition and location will dictate which. If the diagnosis is not urgent, repeat radiographs may be all that is necessary. If there is greater urgency, the panel favors MRI over bone scan because bone scans can be falsely negative in this patient population.	Med
CT area of interest without contrast	1		NS
<b>Rating Scale:</b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

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

**Clinical Condition:****Stress/Insufficiency Fracture, Including Sacrum, Excluding Other Vertebrae****Variant 9:****Suspect insufficiency fracture in osteoporotic patient or patient on long-term corticosteroid therapy; not hip. Radiographs and bone scan or MRI normal at 48 hours.**

Radiologic Procedure	Rating	Comments	<a href="#">RRL*</a>
X-ray area of interest repeat in 10-14 days	9	If diagnosis is nonurgent, repeat radiographs; otherwise go to MRI. Bone scan may be falsely negative in this patient population.	NS
MRI area of interest without contrast repeat in 10-14 days	9	If diagnosis is nonurgent, repeat radiographs; otherwise go to MRI. Bone scan may be falsely negative in this patient population.	None
CT area of interest without contrast	1		NS
<b>Rating Scale:</b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

**Variant 10:****Suspect subacute insufficiency fracture of hip in osteoporotic patient or patient on corticosteroid therapy. Radiographs normal.**

Radiologic Procedure	Rating	Comments	<a href="#">RRL*</a>
MRI hip without contrast	9	A limited MRI exam may yield the diagnosis. May need to proceed to full MRI.	None
NUC Tc-99m bone scan with SPECT hip	5	If MRI contraindicated.	Med
CT hip without contrast	1		Med
X-ray hip repeat in 10-14 days	1		Med
<b>Rating Scale:</b> 1=Least appropriate, 9=Most appropriate			<b>*Relative Radiation Level</b>

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

## Stress/Insufficiency Fracture, Including Sacrum, Excluding Other Vertebrae

Expert Panel on Musculoskeletal Imaging: Richard H. Daffner, MD<sup>1</sup>; Barbara N. Weissman, MD<sup>2</sup>; D. Lee Bennett, MD<sup>3</sup>; Judy S. Blebea, MD<sup>4</sup>; Jon A. Jacobson, MD<sup>5</sup>; William B. Morrison, MD<sup>6</sup>; Charles S. Resnik, MD<sup>7</sup>; Catherine C. Roberts, MD<sup>8</sup>; David A. Rubin, MD<sup>9</sup>; Mark E. Schweitzer, MD<sup>10</sup>; Leanne L. Seeger, MD<sup>11</sup>; Mihra Taljanovic, MD<sup>12</sup>; James N. Wise, MD<sup>13</sup>; William K. Payne, MD.<sup>14</sup>

### Summary of Literature Review

Stress fractures are osseous injuries that result from muscle action on bones. They occur in two varieties: fatigue fractures that are due to abnormal activity on bone of normal mineralization, and insufficiency fractures that are due to normal activity on bones that are deficient in mineral. Both varieties are now being more frequently recognized as the cause of pain in patients. Although many fatigue/insufficiency fractures are self-limited because they heal with or without diagnosis, there is usually value to making the diagnosis. With continued activity, some stress fractures will progress to completion and require more invasive treatment or delay in return to activity. Also the differential diagnosis of stress/insufficiency fractures includes entities that would be treated significantly differently than stress fractures (osteoid osteoma or osteomyelitis in the younger patient, metastases in the older patient).

### Radiographs

The clinical setting is often highly suggestive of the diagnosis of fatigue or insufficiency fractures. Such clinical settings include repetitive or new athletic activity for fatigue fractures, and osteoporosis, irradiated bone, or resumption of activity postarthroplasty for insufficiency fractures. Specific athletic activities often result in specific sites of fatigue fracture. Insufficiency fractures also occur at fairly predictable sites. Thus, radiographic diagnosis using such pattern and site recognition is usually quite specific [1-7]. Late radiographic findings may be quite typical in appearance as well: linear sclerosis, often perpendicular to the major trabecular lines. However, early radiographic findings are less specific (subtle periosteal reaction; “gray cortex sign”) or even nonexistent. Radiographs in stress fractures may be

negative initially in 60%-82% and remain negative in 46%-60%, depending on different specifications of bone scan “gold standards” [4,8,9]. Radiographs are more likely to be negative initially in older or osteoporotic patients with insufficiency fractures. Additionally, radiographs may remain negative depending on the timing of reimaging, the patient’s metabolic bone status, and the type and location of the fracture. Thus, radiographs are specific but significantly insensitive. All references agree that radiographs should be the initial imaging modality; if the findings are conclusive, no further imaging need be performed.

### Bone Scan

Radionuclide bone scans have long been accepted as extremely sensitive for detecting stress/insufficiency fractures; especially if single photon emission computed tomography (SPECT) is used. The objection to the studies quoting high accuracy for bone scan is that, in each, a positive bone scan is taken as the “gold standard” for detecting stress fractures and therefore sensitivity is 100%. However, depending on the staging criteria for bone scan pattern, the abnormalities may in fact be stress reactions rather than actual stress fractures [4,8-12]. Nonetheless, it is clear that bone scans show stress fractures days to weeks earlier than radiographs in many instances, and differentiate between osseous and soft-tissue injury as well. In some cases, the pattern of fracture is such that the diagnosis is secure, and no further imaging is required (for example, the “H sign” or linear and vertical distribution of sacral insufficiency fractures). However, in most cases bone scans lack specificity (with synovitis, arthritis, degenerative joint disease, stress reactions, and tumor appearing similar), and supplemental imaging may be necessary for conclusive diagnosis or to avoid false positives [8].

Because of the sensitivity of bone scan, 80% of all fractures show some scan abnormality 24 hours post-injury and 95% at 72 hours [10]. A normal bone scan generally excludes a diagnosis of stress/insufficiency fracture, and the patient may return to normal activity. However, there are exceptions. Elderly or osteoporotic patients may have a delay in bone scan activity [10,11] that may last several days. Patients using corticosteroids may also have less sensitive bone scan results [13,14].

### Computed Tomography

Because bone scan is often nonspecific, the length of time necessary for the examination, and the frequency with which supplemental imaging is required, there is a growing body of literature suggesting that cross sectional imaging should supersede bone scan as the imaging of choice for stress fracture when the radiograph is negative. There are specific sites for which computed tomography

<sup>1</sup>Principal Author and Panel Chair, Allegheny General Hospital, Pittsburgh, Pa; <sup>2</sup>Panel Vice-chair, Brigham & Women’s Hospital, Boston, Mass; <sup>3</sup>University of Iowa Health Center, Iowa City, Iowa; <sup>4</sup>University of Pennsylvania Hospital, Philadelphia, Pa; <sup>5</sup>University of Michigan Medical Center, Ann Arbor, Mich; <sup>6</sup>Thomas Jefferson University Hospital, Philadelphia, Pa; <sup>7</sup>University of Maryland School of Medicine, Baltimore, Md; <sup>8</sup>Mayo Clinic, Phoenix, Ariz; <sup>9</sup>Mallinckrodt Institute of Radiology, Saint Louis, Mo; <sup>10</sup>Hospital for Joint Diseases, New York, NY; <sup>11</sup>David Geffen School of Medicine, University of California Los Angeles, Los Angeles, Calif; <sup>12</sup>University of Arizona Health Sciences Center, Tucson, Ariz; <sup>13</sup>University of Arkansas for Medical Sciences, Little Rock, Ark; <sup>14</sup>American Academy of Orthopaedic Surgeons, Chicago, Ill.

Reprint requests to: Department of Quality & Safety, American College of Radiology, 1891 Preston White Drive, Reston, VA 20191-4397.

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

(CT) is particularly well-suited, such as sacrum and tarsal navicular [6,7,15,16].

However, axial CT alone may have false negatives due to the constraint of the axial plane (in one study, half of stress fractures were inadequately demonstrated on CT [6,17]. Therefore, if CT is used to confirm stress fracture in a long bone, reformatting is necessary. Fine detail may be achieved using thinner sections and high detector (16-64 slices) scanners.

### **Magnetic Resonance Imaging**

Magnetic resonance imaging (MRI) is extremely sensitive and appears to demonstrate stress abnormalities as early as bone scan does and with as much sensitivity [13,18-24]. Indeed, the recent literature favors MRI as the procedure of choice for making an early diagnosis of either variety of stress fracture [25-31]. In this regard, it outperforms radiography, radionuclide scanning, and CT. Short tau inversion recovery (STIR) sequences are emerging as the favored initial sequence [20,32] for MRI screening. With a small field of view (FOV), STIR and/or T1 imaging will usually demonstrate a fracture line, surrounded by edema. In the absence of an actual stress fracture, stress reaction or muscle/tendon injuries are identified in the STIR sequence. Thus, a careful MRI may be as sensitive as a bone scan, but also considerably more specific [28,30]. One study suggests that MRI exam of an osseous stress injury may contain prognostic as well as diagnostic information [33], with demonstration of an actual fracture line or cortical signal portending that a longer healing time will be required.

The critical time for MRI becoming positive has not yet been established, although it seems that the edema pattern would be present within hours of the injury. Furthermore, the linearity in the distribution of abnormal signal is highly suggestive of stress fracture and serves to differentiate these injuries from bone tumors, which tend to have a globular pattern [16].

The choice of cross sectional imaging modality has not always been clear cut. Earlier studies demonstrated that the MRI pattern was nonspecific and even confusing when only edema and not the fracture line is shown [2,34]. This problem seems particularly severe in differentiating sacral or pelvic insufficiency fractures from metastases [1,7,15,35-37]. These fractures are being recognized with greater frequency as knowledge of their occurrence has become more widely known [15,25,35,36,38,39]. Compounding the problem is the fact that many patients suffering from these insufficiency fractures have a history of previous malignancy, including treatment with radiation (which increases the risk of insufficiency fracture). Overreliance on nonspecific low-signal T1 and high-signal T2 MRI patterns can lead to misdiagnosis of stress fractures as more aggressive lesions. The use of in-phase and out-of-phase MR

sequences is most reliable in differentiating benign stress fractures from pathologic fractures [40-42]. STIR sequences can be helpful in that they are more likely to demonstrate not only the edema pattern but also the fracture lines themselves. In some of these cases, CT may be necessary to add specificity to the diagnosis.

MRI may, however, also demonstrate other reasons for occult pelvic pain, such as soft-tissue abnormality or the supra-acetabular stress fractures recently described in some osteoporotic patients [38,39]. Conversely, it is recommended that MRI for hip fractures also include the sacrum, since stress fractures of the sacrum appear to be associated with stress-related hip pain in young adult patients [25,43,44].

MRI of long bones often shows the fracture line itself. In this case, MRI is not only sensitive but also specific (fracture line seen in 11 of 14 stress fractures [24], 7 of 9 hip fractures [19], and 13 of 13 true positive hip fractures [45]). The sites where this phenomenon has been evaluated most completely are the hip and acetabulum, which may yield false negatives early on both radiographs and bone scan of the osteoporotic patient [37,39,43,45]. Some experts recommend that a single T1 MRI sequence in the plane of interest be performed and initially evaluated when stress fracture is suspected. If a fracture line is clearly seen, the examination may be terminated. If the question persists after the single sequence, other MRI sequences may be used for more complete examination (eg, STIR or FSE T2 sequences for even more sensitive evaluation of marrow edema, or nearby soft-tissue injury). Intravenous contrast should not be required. In a younger patient population (eg, military recruits), STIR imaging was found to have a higher accuracy than T1 imaging [31,32] and may be chosen as the initial MRI sequence.

Another circumstance that deserves specific attention is the longitudinal stress fracture, particularly in the tibia. Up to 25% may appear normal on radiographs, but CT or MRI findings are characteristic [22,46,47]. MRI is very sensitive to the bone marrow edema accompanying these longitudinal fractures, and may give a misleadingly aggressive appearance [46].

Ultrasound has not been shown to be useful in diagnosing longitudinal stress fractures [48].

### **Summary**

In summary, patients with suspected fatigue or insufficiency fractures should be imaged initially with radiographs. In many instances the abnormality will be apparent. If radiographs are not adequate to solve the clinical problem, MRI is the clear-cut choice for imaging, particularly in the elite athlete, in the elderly, and in those patients who are dependent on using the injured limb in their work. CT, particularly in cases of insufficiency

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

fractures of the sacrum and pelvis, may be needed to confirm the diagnosis.

### Relative Radiation Level Information

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

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

\*RRL assignments are not included for some examinations. The RRL assignments for the NS (not specified) exams cannot be made because the RRL depends on the region of the body exposed to ionizing radiation, and the body part will vary as a function of the clinical situation.

### References

1. Abe H, Nakamura M, Takahashi S, Maruoka S, Ogawa Y, Sakamoto K. Radiation-induced insufficiency fractures of the pelvis: evaluation with 99mTc-methylene diphosphonate scintigraphy. *AJR* 1992; 158(3):599-602.
2. Daffner RH, Pavlov H. Stress fractures: current concepts. *AJR* 1992; 159(2):245-252.
3. De Smet AA, Neff JR. Pubic and sacral insufficiency fractures: clinical course and radiologic findings. *AJR* 1985; 145(3):601-606.
4. Greaney RB, Gerber FH, Laughlin RL, et al. Distribution and natural history of stress fractures in U.S. Marine recruits. *Radiology* 1983; 146(2):339-346.
5. Harrington T, Crichton KJ, Anderson IF. Overuse ballet injury of the base of the second metatarsal. A diagnostic problem. *Am J Sports Med* 1993; 21(4):591-598.
6. Kiss ZS, Khan KM, Fuller PJ. Stress fractures of the tarsal navicular bone: CT findings in 55 cases. *AJR* 1993; 160(1):111-115.
7. Peh WC, Evans NS. Pelvic insufficiency fractures in the elderly. *Ann Acad Med Singapore* 1993; 22(5):818-822.
8. Geslien GE, Thrall JH, Espinosa JL, Older RA. Early detection of stress fractures using 99mTc-polyphosphate. *Radiology* 1976; 121(3 Pt. 1):683-687.
9. Zwas ST, Elkanovitch R, Frank G. Interpretation and classification of bone scintigraphic findings in stress fractures. *J Nucl Med* 1987; 28(4):452-457.
10. Matin P. The appearance of bone scans following fractures, including immediate and long-term studies. *J Nucl Med* 1979; 20(12):1227-1231.

11. Matin P. Basic principles of nuclear medicine techniques for detection and evaluation of trauma and sports medicine injuries. *Semin Nucl Med* 1988; 18(2):90-112.
12. Wilcox JR, Jr., Moniot AL, Green JP. Bone scanning in the evaluation of exercise-related stress injuries. *Radiology* 1977; 123(3):699-703.
13. Scott S, Alazraki N, Manaster B. Failure of bone scanning to detect fractures in a woman on chronic steroid therapy. *Skeletal Radiol* 1984; 12(3):204-207.
14. Scott SM, Manaster BJ, Alazraki N, Wooten WW, Murphy K. Technetium-99m imaging of bone trauma: reduced sensitivity caused by hydrocortisone in rabbits. *AJR* 1987; 148(6):1175-1178.
15. Blomlie V, Lien HH, Iversen T, Winderen M, Tvera K. Radiation-induced insufficiency fractures of the sacrum: evaluation with MR imaging. *Radiology* 1993; 188(1):241-244.
16. Fayad LM, Kawamoto S, Kamel IR, et al. Distinction of long bone stress fractures from pathologic fractures on cross-sectional imaging: how successful are we? *AJR* 2005; 185(4):915-924.
17. Groves AM, Cheow HK, Balan KK, Housden BA, Bearcroft PW, Dixon AK. 16-Detector multislice CT in the detection of stress fractures: a comparison with skeletal scintigraphy. *Clin Radiol* 2005; 60(10):1100-1105.
18. Hatem SF, Recht MP, Proffitt B. MRI of Little Leaguer's shoulder. *Skeletal Radiol* 2006; 35(2):103-106.
19. Deutsch AL, Mink JH, Waxman AD. Occult fractures of the proximal femur: MR imaging. *Radiology* 1989; 170(1 Pt 1):113-116.
20. Ishibashi Y, Okamura Y, Otsuka H, Nishizawa K, Sasaki T, Toh S. Comparison of scintigraphy and magnetic resonance imaging for stress injuries of bone. *Clin J Sport Med* 2002; 12(2):79-84.
21. Kiuru MJ, Pihlajamaki HK, Hietanen HJ, Ahovuo JA. MR imaging, bone scintigraphy, and radiography in bone stress injuries of the pelvis and the lower extremity. *Acta Radiol* 2002; 43(2):207-212.
22. Lassus J, Tulikoura I, Kontinen YT, Salo J, Santavirta S. Bone stress injuries of the lower extremity: a review. *Acta Orthop Scand* 2002; 73(3):359-368.
23. Lee JK, Yao L. Stress fractures: MR imaging. *Radiology* 1988; 169(1):217-220.
24. Meyers SP, Wiener SN. Magnetic resonance imaging features of fractures using the short tau inversion recovery (STIR) sequence: correlation with radiographic findings. *Skeletal Radiol* 1991; 20(7):499-507.
25. Ahovuo JA, Kiuru MJ, Visuri T. Fatigue stress fractures of the sacrum: diagnosis with MR imaging. *Eur Radiol* 2004; 14(3):500-505.
26. Anderson MW. Imaging of upper extremity stress fractures in the athlete. *Clin Sports Med* 2006; 25(3):489-504, vii.
27. Aoki Y, Yasuda K, Tohyama H, Ito H, Minami A. Magnetic resonance imaging in stress fractures and shin splints. *Clin Orthop Relat Res* 2004; (421):260-267.
28. Gaeta M, Minutoli F, Scribano E, et al. CT and MR imaging findings in athletes with early tibial stress injuries: comparison with bone scintigraphy findings and emphasis on cortical abnormalities. *Radiology* 2005; 235(2):553-561.
29. Lee SH, Baek JR, Han SB, Park SW. Stress fractures of the femoral diaphysis in children: a report of 5 cases and review of literature. *J Pediatr Orthop* 2005; 25(6):734-738.
30. Muthukumar T, Butt SH, Cassar-Pullicino VN. Stress fractures and related disorders in foot and ankle: plain films, scintigraphy, CT, and MR imaging. *Semin Musculoskelet Radiol* 2005; 9(3):210-226.
31. Sofka CM. Imaging of stress fractures. *Clin Sports Med* 2006; 25(1):53-62, viii.
32. Ahovuo JA, Kiuru MJ, Kinnunen JJ, Haapamaki V, Pihlajamaki HK. MR imaging of fatigue stress injuries to bones: intra- and interobserver agreement. *Magn Reson Imaging* 2002; 20(5):401-406.
33. Yao L, Johnson C, Gentili A, Lee JK, Seeger LL. Stress injuries of bone: analysis of MR imaging staging criteria. *Acad Radiol* 1998; 5(1):34-40.

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

34. Hayes CW, Conway WF, Sundaram M. Misleading aggressive MR imaging appearance of some benign musculoskeletal lesions. *Radiographics* 1992; 12(6):1119-1134; discussion 1135-1116.
35. Brahme SK, Cervilla V, Vint V, Cooper K, Kortman K, Resnick D. Magnetic resonance appearance of sacral insufficiency fractures. *Skeletal Radiol* 1990; 19(7):489-493.
36. Cooper KL. Insufficiency stress fractures. *Curr Probl Diagn Radiol* 1994; 23(2):29-68.
37. Soubrier M, Dubost JJ, Boisgard S, et al. Insufficiency fracture. A survey of 60 cases and review of the literature. *Joint Bone Spine* 2003; 70(3):209-218.
38. Grangier C, Garcia J, Howarth NR, May M, Rossier P. Role of MRI in the diagnosis of insufficiency fractures of the sacrum and acetabular roof. *Skeletal Radiol* 1997; 26(9):517-524.
39. Otte MT, Helms CA, Fritz RC. MR imaging of supra-acetabular insufficiency fractures. *Skeletal Radiol* 1997; 26(5):279-283.
40. Disler DG, McCauley TR, Ratner LM, Kesack CD, Cooper JA. In-phase and out-of-phase MR imaging of bone marrow: prediction of neoplasia based on the detection of coexistent fat and water. *AJR* 1997; 169(5):1439-1447.
41. Eito K, Waka S, Naoko N, Makoto A, Atsuko H. Vertebral neoplastic compression fractures: assessment by dual-phase chemical shift imaging. *J Magn Reson Imaging* 2004; 20(6):1020-1024.
42. Erly WK, Oh ES, Outwater EK. The utility of in-phase/opposed-phase imaging in differentiating malignancy from acute benign compression fractures of the spine. *AJNR Am J Neuroradiol* 2006; 27(6):1183-1188.
43. Bencardino JT, Kassirjian A, Palmer WE. Magnetic resonance imaging of the hip: sports-related injuries. *Top Magn Reson Imaging* 2003; 14(2):145-160.
44. Kiuru MJ, Pihlajamaki HK, Ahovuo JA. Fatigue stress injuries of the pelvic bones and proximal femur: evaluation with MR imaging. *Eur Radiol* 2003; 13(3):605-611.
45. Quinn SF, McCarthy JL. Prospective evaluation of patients with suspected hip fracture and indeterminate radiographs: use of T1-weighted MR images. *Radiology* 1993; 187(2):469-471.
46. Feydy A, Drape J, Beret E, et al. Longitudinal stress fractures of the tibia: comparative study of CT and MR imaging. *Eur Radiol* 1998; 8(4):598-602.
47. Shearman CM, Brandser EA, Parman LM, et al. Longitudinal tibial stress fractures: a report of eight cases and review of the literature. *J Comput Assist Tomogr* 1998; 22(2):265-269.
48. Romani WA, Perrin DH, Dussault RG, Ball DW, Kahler DM. Identification of tibial stress fractures using therapeutic continuous ultrasound. *J Orthop Sports Phys Ther* 2000; 30(8):444-452.

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