American College of Radiology
ACR Appropriateness Criteria®
Primary Bone Tumors

Variant 1: **Suspect primary bone tumor. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography area of interest	Usually Appropriate	Varies
CT area of interest with IV contrast	Usually Not Appropriate	Varies
CT area of interest without and with IV contrast	Usually Not Appropriate	Varies
CT area of interest without IV contrast	Usually Not Appropriate	Varies
FDG-PET/CT whole body	Usually Not Appropriate	☢☢☢☢
MRI area of interest without and with IV contrast	Usually Not Appropriate	O
MRI area of interest without IV contrast	Usually Not Appropriate	O
Bone scan whole body	Usually Not Appropriate	☢☢☢
US area of interest	Usually Not Appropriate	O

Variant 2: **Suspect primary bone tumor. Radiographs negative or do not explain symptoms. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI area of interest without and with IV contrast	Usually Appropriate	O
MRI area of interest without IV contrast	Usually Appropriate	O
CT area of interest without IV contrast	May Be Appropriate	Varies
CT area of interest without and with IV contrast	May Be Appropriate	Varies
CT area of interest with IV contrast	Usually Not Appropriate	Varies
FDG-PET/CT whole body	Usually Not Appropriate	☢☢☢☢
Bone scan whole body	Usually Not Appropriate	☢☢☢
US area of interest	Usually Not Appropriate	O

Variant 3: **Suspect primary bone tumor. Benign radiographic features. Not osteoid osteoma. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI area of interest without and with IV contrast	May Be Appropriate	O
MRI area of interest without IV contrast	May Be Appropriate	O
CT area of interest without IV contrast	May Be Appropriate	Varies
CT area of interest with IV contrast	Usually Not Appropriate	Varies
CT area of interest without and with IV contrast	Usually Not Appropriate	Varies
FDG-PET/CT whole body	Usually Not Appropriate	☢☢☢☢
Bone scan whole body	Usually Not Appropriate	☢☢☢
US area of interest	Usually Not Appropriate	O

Variant 4: **Suspect primary bone tumor. Radiographs or clinical presentation suggest osteoid osteoma. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
CT area of interest without IV contrast	Usually Appropriate	Varies
CT area of interest without and with IV contrast	May Be Appropriate (Disagreement)	Varies
MRI area of interest without and with IV contrast	May Be Appropriate	O
MRI area of interest without IV contrast	May Be Appropriate	O
Bone scan whole body with SPECT or SPECT/CT area of interest	May Be Appropriate	☢☢☢
Bone scan whole body	Usually Not Appropriate	☢☢☢
CT area of interest with IV contrast	Usually Not Appropriate	Varies
FDG-PET/CT whole body	Usually Not Appropriate	☢☢☢☢
US area of interest	Usually Not Appropriate	O

Variant 5: **Suspect primary bone tumor. Lesion on radiographs. Indeterminate or aggressive appearance for malignancy. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI area of interest without and with IV contrast	Usually Appropriate	O
MRI area of interest without IV contrast	May Be Appropriate	O
CT area of interest without and with IV contrast	May Be Appropriate (Disagreement)	Varies
CT area of interest without IV contrast	May Be Appropriate	Varies
FDG-PET/CT whole body	May Be Appropriate	☢☢☢☢
Bone scan whole body with SPECT or SPECT/CT area of interest	May Be Appropriate	☢☢☢
Bone scan whole body	Usually Not Appropriate	☢☢☢
CT area of interest with IV contrast	Usually Not Appropriate	Varies
Radiography skeletal survey	Usually Not Appropriate	☢☢☢
US area of interest	Usually Not Appropriate	O

Variant 6: **"Incidental" osseous lesion on MRI or CT scan for unrelated indication. Suspect primary bone tumor. Not clearly benign. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography area of interest	Usually Appropriate	Varies
MRI area of interest without and with IV contrast	May Be Appropriate	O
CT area of interest without and with IV contrast	May Be Appropriate (Disagreement)	Varies
CT area of interest without IV contrast	May Be Appropriate	Varies
MRI area of interest without IV contrast	May Be Appropriate	O
Bone scan whole body	May Be Appropriate	☢☢☢
FDG-PET/CT whole body	Usually Not Appropriate	☢☢☢☢
CT area of interest with IV contrast	Usually Not Appropriate	Varies
US area of interest	Usually Not Appropriate	O

PRIMARY BONE TUMORS

Expert Panel on Musculoskeletal Imaging: Joseph M. Bestic, MD[a]; Daniel E. Wessell, MD, PhD[b]; Francesca D. Beaman, MD[c]; R. Carter Cassidy, MD[d]; Gregory J. Czuczman, MD[e]; Jennifer L. Demertzis, MD[f]; Leon Lenchik, MD[g]; Kambiz Motamedi, MD[h]; Jennifer L. Pierce, MD[i]; Akash Sharma, MD, PhD, MBA[j]; Andrew E. Sloan, MD[k]; Khoi Than, MD[l]; Eric A. Walker, MD, MHA[m]; Elizabeth Ying-Kou Yung, MD[n]; Mark J. Kransdorf, MD.[o]

Summary of Literature Review

Introduction/Background

The term "bone tumor" may be applied to a broad range of entities including primary and metastatic neoplasms as well as a variety of tumor-like lesions related to developmental, metabolic, hematopoietic, lymphatic, or reactive abnormalities that affect bone. This document addresses tumors and tumor-like conditions that occur primarily in bone and specifically excludes metastatic involvement of bone from both musculoskeletal and nonmusculoskeletal primary malignancies, such as lymphoma or plasma cell myeloma that may present as a solitary osseous lesion. Primary bone tumors exclusively seen in the pediatric population are also excluded.

Primary bone tumors are conventionally classified by the World Health Organization as benign, intermediate (locally aggressive or rarely metastasizing), or malignant [1]. Benign tumors include a wide variety of developmental abnormalities and true neoplasms. Because most benign bone tumors are asymptomatic, the true incidence of these tumors is unknown, although they are not uncommon. Intermediate tumors include lesions such as giant cell tumor, osteoblastoma, and desmoplastic fibroma. Primary malignant bone tumors may also arise from malignant mesenchymal cells (sarcomas). Primary malignant bone tumors are quite rare, with an estimated incidence of 1 case per 100,000 persons per year [2].

Diagnosis of benign and malignant primary bone tumors relies on a coordinated evaluation of both clinical and radiologic information. Many primary bone tumors can be effectively stratified with respect to typical age of presentation as well as lesion size, location, and number. Classically, radiographs have played a substantial role in the characterization of primary bone tumors. An assortment of radiographic features, including tumor margin, periosteal reaction, and matrix mineralization, may be used to assess the biological activity of a bone lesion [3-6]. An asymptomatic nonaggressive-appearing lesion incidentally found on radiographs may, in many cases, require no further evaluation. In cases in which clinical or radiographic features are indeterminate or additional anatomic information is required, advanced imaging modalities, such as CT, MRI, or nuclear medicine, may provide a complementary role in the diagnosis and treatment stratification of primary bone tumors.

Because primary bone sarcomas are rare, there is sparse level 1 evidence in the literature specifically addressing their imaging evaluation. The recommendations contained herein are based on assessment of the available literature and on the experience of the members of the ACR Appropriateness Criteria Expert Panel on Musculoskeletal Imaging.

This document applies to the evaluation of osseous lesions throughout the entire body. Generally, bone tumors are most common in the long bones [1], and consequently, recommendations for imaging are for the most part based on this. When lesions occur in locations with complex osseous anatomy, such as the skull, spine, pelvis, or small bones of the hand or foot, CT may be a more suitable initial imaging modality. Similarly, when a lesion occurs in a rib or area in which respiratory motion can be an issue, MRI may not be a suitable imaging modality. As noted within the document, the following recommendations must be adapted by the user, based on lesion size, location, and suspected biological aggressiveness.

[a]Research Author, Mayo Clinic, Jacksonville, Florida. [b]Panel Vice-Chair, Mayo Clinic, Jacksonville, Florida. [c]Panel Chair, University of Kentucky, Lexington, Kentucky. [d]UK Healthcare Spine and Total Joint Service, Lexington, Kentucky; American Academy of Orthopaedic Surgeons. [e]Radiology Imaging Associates, Denver, Colorado. [f]Diagnostic Imaging Associates, Chesterfield, Missouri. [g]Wake Forest University School of Medicine, Winston Salem, North Carolina. [h]David Geffen School of Medicine at UCLA, Los Angeles, California. [i]University of Virginia, Charlottesville, Virginia. [j]Mayo Clinic Florida, Jacksonville, Florida. [k]University Hospitals Cleveland Medical Center and Case Western Reserve University School of Medicine, Cleveland, Ohio; Neurosurgery Expert. [l]Oregon Health & Science University, Portland, Oregon; Neurosurgery Expert. [m]Penn State Milton S. Hershey Medical Center, Hershey, Pennsylvania and Uniformed Services University of the Health Sciences, Bethesda, Maryland. [n]Nuclear Radiologist, Weston, Connecticut. [o]Specialty Chair, Mayo Clinic, Phoenix, Arizona.

Reprint requests to: publications@acr.org

The recommendations for all variants in this document apply to the following body regions: lower extremity, upper extremity, ribs, pelvis, skull, and spine.

Discussion of Procedures by Variant

Variant 1: Suspect primary bone tumor. Initial imaging.

CT Area of Interest

CT is not routinely used in the initial evaluation of primary bone tumors. There is no relevant literature regarding the use of CT in the initial imaging of primary bone tumors.

FDG-PET/CT Whole Body

PET using the tracer fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)/CT is not routinely used in the initial evaluation of primary bone tumors. There is no relevant literature regarding the use of FDG-PET/CT in the initial imaging of primary bone tumors.

MRI Area of Interest

MRI is not routinely used in the initial evaluation of primary bone tumors. There is no relevant literature regarding the use of MRI in the initial imaging of primary bone tumors.

Radiography Area of Interest

Radiographs remain the most appropriate imaging modality for screening and initial characterization of primary bone tumors. Radiographs provide an accurate means by which to evaluate primary bone tumors. Radiographs effectively provide information in regard to tumor location, size, and shape, as well as evidence of tumor biological activity [3]. Tumor margin and periosteal reaction provide a reliable index of biological potential of the tumor, whereas matrix, if identified, is a key to the underlying histology [3-6]. Although the utility of radiographs in stratifying bone lesions by biological activity is well established, there is sparse literature documenting concrete values on accuracy. A prospective study evaluating 200 consecutive bone tumors of the hand showed that subjective grading of tumors based on radiographic features provided a correct categorization of tumor grade (benign versus malignant) in 82.5% of cases [7]. In a retrospective study applying a modified Lodwick-Madewell grading system to categorize 183 bone tumors, Caracciolo et al [8] found that a low radiographic grade assignment correlates with benignity and that increasing grade correlates with an increasing risk of malignancy. It should be noted that accurate radiographic characterization of some primary bone tumors (such as low-grade cartilage lesions) is inherently difficult because of overlapping radiographic features of some benign and malignant chondroid lesions. Crim et al [9] performed a retrospective review of 53 cases of low-grade cartilage lesions (enchondroma and grade 1 chondrosarcoma) and found that radiographs suggested the correct diagnosis of enchondroma in 67.2% of cases and the correct diagnosis of chondrosarcoma in only 20.8% of cases. In a retrospective analysis of 35 enchondromas and 43 central grade 1 chondrosarcomas, Geirnaerdt et al [10] found that morphologic features seen on radiographs in combination with clinical symptoms did not improve the ability to differentiate between enchondromas and central grade 1 chondrosarcomas.

Bone Scan Whole Body

Bone scan is not routinely used in the initial evaluation of primary bone tumors. There is no relevant literature regarding the use of Tc-99m bone scan in the initial imaging of primary bone tumors.

US Area of Interest

Ultrasound (US) is not routinely used in the initial evaluation of primary bone tumors. There is no relevant literature regarding the use of US in the initial imaging of primary bone tumors.

Variant 2: Suspect primary bone tumor. Radiographs negative or do not explain symptoms. Next imaging study.

In cases in which radiographs are negative or radiographic findings do not adequately explain the symptoms, further evaluation with advanced imaging (such as MRI or CT) should be contemplated based on history and level of clinical concern.

CT Area of Interest

In cases in which radiographs are negative or fail to adequately explain symptoms, CT can be a helpful tool in facilitating detection of bony abnormalities, such as nondisplaced fractures, subtle periosteal reaction, or occult bone tumors. CT can be especially helpful in evaluating regions of complex or overlapping osseous anatomy, in which radiographic evaluation can be limited. In a retrospective study of 47 patients with negative radiographic

findings and positive bone scintigraphy findings specifically involving the ribs, CT was effective in detecting rib fractures and avoiding further unnecessary examinations [11]. CT is also a viable imaging alternative for patients who cannot receive an MRI. Some cases may benefit from both MRI and CT because these modalities provide complementary information regarding soft-tissue (often better evaluated on MRI) and matrix mineralization (often better evaluated on CT).

There is no relevant literature specifically regarding the use of CT with intravenous (IV) contrast or CT without and with IV contrast in the evaluation of suspected primary bone tumor with negative or equivocal radiographs or radiographs that do not explain symptoms. Contrast may be helpful if a soft-tissue component is suspected. However, if contrast is given, CT without and with IV contrast is preferred because it allows differentiation of areas of contrast enhancement from areas of osseous matrix production.

FDG-PET/CT Whole Body
FDG-PET/CT is not routinely used for the evaluation of primary bone tumors in patients with positive localized or regional symptoms and negative radiographs or findings that do not explain symptoms. Although FDG-PET/CT can detect metabolically active tumors, there is no relevant literature regarding the use of FDG-PET/CT in patients with positive localized or regional symptoms and negative radiographs or findings that do not explain symptoms.

MRI Area of Interest
Although there is no relevant literature specifically regarding the general use of MRI in this setting, the excellent soft-tissue characterization afforded by MRI facilitates detection of radiographically occult pathology within both the bone and the surrounding tissues. In addition to its ability to detect occult bone tumors, MRI can identify other radiographically occult abnormalities, such as osseous contusion, developing stress fracture, infection, or regional soft-tissue injury, that may account for the patient's symptoms. There is evidence that MRI is superior to bone scan [12] as detailed in the bone scan section below. For these reasons, MRI is considered the study of choice in patients with suspected bone tumor that is due to positive symptoms but negative radiographs. Although contrast may be especially useful in biopsy planning and assessment of response to therapy, it is not always required.

Bone Scan Whole Body
Despite its historical utility in detecting radiographically occult bone abnormalities, studies that are more recent have shown that MRI is superior in this role. A retrospective analysis comparing the sensitivity of MRI and scintigraphy in the detection of malignant bone tumors in 106 patients showed that MRI revealed a focal abnormality compatible with tumor that was occult on scintigraphy in 28% of cases [12]. Although not typically the next imaging study, bone scan remains a viable imaging option in select cases in which MRI is not clinically feasible as well as in cases that require evaluation of the full extent and distribution of disease because it can provide a comprehensive evaluation of the entire skeleton.

US Area of Interest
Although US may be helpful in detecting regional soft-tissue abnormalities that could explain symptoms, US is quite limited in its ability to evaluate bone. There is no relevant literature regarding the use of US for the evaluation of primary bone tumors in patients with positive localized or regional symptoms and negative radiographs or findings that do not explain symptoms.

Variant 3: Suspect primary bone tumor. Benign radiographic features. Not osteoid osteoma. Next imaging study.

An asymptomatic benign-appearing lesion on radiographs is usually an incidental finding and typically requires no further imaging evaluation. If the lesion is symptomatic, please consult Variant 2.

CT Area of Interest
CT is not routinely used in the evaluation of lesions that are definitely benign on radiographs. There is no relevant literature regarding the use of CT in the evaluation of definitely benign primary bone tumors. However, if such lesions are symptomatic, CT imaging without IV contrast may be useful to identify complications or for surgical planning.

FDG-PET/CT Whole Body
FDG-PET/CT is not routinely used in the evaluation of lesions that are definitely benign on radiographs. There is no relevant literature regarding the use of FDG-PET/CT in the evaluation of definitely benign primary bone tumors.

MRI Area of Interest
MRI is not routinely used in the evaluation of lesions that are definitely benign on radiographs. If such lesions are symptomatic, MRI may be useful to identify unusual complications, such as stress fracture, secondary aneurysmal bone cyst formation, or malignant transformation [13].

Bone Scan Whole Body
Bone scan is not routinely used in the evaluation of lesions that are definitely benign on radiographs. There is no relevant literature regarding the use of Tc-99m bone scan in the evaluation of definitely benign primary bone tumors.

US Area of Interest
US is not routinely used in the evaluation of lesions that are definitely benign on radiographs. There is no relevant literature regarding the use of US in the evaluation of definitely benign primary bone tumors.

Variant 4: Suspect primary bone tumor. Radiographs or clinical presentation suggest osteoid osteoma. Next imaging study.

CT Area of Interest
CT is considered the optimal imaging modality in patients with suspected osteoid osteoma. CT is preferred over MRI when osteoid osteoma is strongly suspected because it is extremely sensitive for detection and precise delineation of the nidus [14], which is important both for diagnosis and treatment. In a study including 19 patients with histologically proven osteoid osteoma who underwent CT and MRI before excision of the lesion, Assoun et al [15] found that CT was more accurate than MRI in detection of the osteoid osteoma nidus in 63% of cases.

There is no relevant literature specifically regarding the use of CT without and with IV contrast in the evaluation of suspected primary bone tumor with negative or equivocal radiographs or radiographs that do not explain symptoms. However, if contrast is given, CT without and with IV contrast is preferred because it allows differentiation of areas of contrast enhancement from areas of osseous matrix production.

CT perfusion is a dynamic without and with IV contrast CT examination, which facilitates further characterization in the setting of suspected osteoid osteoma. A comparative study looking at CT perfusion parameters of 15 patients with a final diagnosis of osteoid osteoma, 15 patients with lesions that mimic osteoid osteomas, and 26 patients with other bone lytic lesions showed that enhancement curve morphology of the osteoid osteomas was significantly different from its mimickers. All osteoid osteomas had early enhancement with a delay between nidus and arterial peak below 30 seconds. Eighty percent of the mimickers demonstrated a slow and progressive pattern of enhancement. The perfusion parameters of the other lytic bone lesions were similar to those of the osteoid osteomas in 46.1% of the patients, indicating that early enhancement is suggestive but not pathognomonic of osteoid osteomas [16].

FDG-PET/CT Whole Body
FDG-PET/CT is not routinely used in the evaluation of suspected osteoid osteoma. There is no relevant literature regarding the use of FDG-PET/CT in the evaluation of suspected osteoid osteoma.

MRI Area of Interest
MRI is generally considered inferior to CT in the evaluation of suspected osteoid osteoma because it may fail to demonstrate the typical nidus and can present a confounding imaging appearance. Davies et al [17] performed a retrospective review of the MRI findings of 43 patients with osteoid osteoma and then compared the results with those of other imaging modalities. The authors found that the potential for a missed diagnosis of osteoid osteoma on MRI was 35%. They cautioned that osteoid osteoma may be difficult to identify on MRI and the imaging features may be easily misinterpreted. In a study including 19 patients with histologically proven osteoid osteoma who underwent CT and MRI before excision of the lesion, Assoun et al [15] found that MRI was better than CT in showing intramedullary and soft-tissue changes in all cases. However, the authors cautioned that such findings on MRI may produce a misleading aggressive appearance. Liu et al [18] performed a retrospective study including 11 patients with pathologically proven osteoid osteomas who underwent nonenhanced MRI, dynamic gadolinium-enhanced MRI, and CT. They showed that compared with CT, dynamic gadolinium-enhanced MRI demonstrated the osteoid osteoma equally well in 8 of 11 patients and with better conspicuity in 3 of 11 patients, although this difference was not statistically significant ($P = .69$). Furthermore, the dynamic gadolinium-enhanced MRIs demonstrated the osteoid osteomas significantly better than the nonenhanced T1-weighted ($P < .001$) and T2-weighted ($P < .001$) MRIs. In the majority of cases, peak enhancement of the osteoid osteoma occurred in the

arterial phase with early partial washout. However, MRI without IV contrast or MRI without and with IV contrast may be useful in some cases to identify alternative diagnoses such as osteomyelitis.

Bone Scan Whole Body
Bone scan is sensitive for the detection of osteoid osteoma but lacks specificity [19].

Bone Scan Whole Body with SPECT or SPECT/CT Area of Interest
Bone scan is sensitive for the detection of osteoid osteoma but lacks specificity. Single-photon emission computed tomography (SPECT) or SPECT/CT may help improve specificity [19].

US Area of Interest
US is not routinely used in the evaluation of suspected osteoid osteoma. There is no relevant literature regarding the use of US in the evaluation of suspected osteoid osteoma.

Variant 5: Suspect primary bone tumor. Lesion on radiographs. Indeterminate or aggressive appearance for malignancy. Next imaging study.

Lesions seen on radiographs that are not definitely benign often require additional characterization using advanced imaging studies such as MRI or CT. The next best imaging examination is not always clearly defined because the choice will be influenced by the radiographic appearance of the lesion, location, number of lesions, availability of imaging equipment, plan for biopsy/treatment, as well as underlying patient-specific clinical parameters.

CT Area of Interest
CT continues to play a role in the evaluation of indeterminate bone lesions discovered on radiographs, particularly in lesions with mineralized matrix or in suspected cases of osteoid osteoma (see Variant 4). Both MRI and CT have been used to evaluate the degree of cortical involvement in chondroid lesions [20]. In comparison with radiographs and MRI, CT has been shown to better delineate the presence of cortical destruction and the character of matrix mineralization patterns in patients with clear cell chondrosarcoma [21]. In a retrospective review of 40 pathologically confirmed telangiectatic osteosarcomas, Murphey et al [22] noted that CT was the optimal imaging modality for demonstration of subtle matrix mineralization seen in 85% of cases in the intraosseous or soft-tissue components of the lesion. Not all studies conclude that one modality, CT or MRI, is better than the other. A multi-institutional collaborative study assessing the relative accuracy of CT and MRI in the local staging of primary malignant musculoskeletal neoplasms showed no statistically significant difference between CT and MRI in determining tumor involvement of muscle, bone, joints, or neurovascular structures. Furthermore, the combined interpretation of CT and MRI did not significantly improve accuracy [23]. Advanced CT techniques, such as dual-energy CT, have shown promise in differentiating malignant from nonmalignant tumors, although further research in this area is needed [24]. MRI is generally considered the preferred imaging modality for staging of bone tumors. Some cases may benefit from both MRI and CT because these modalities provide complementary information regarding soft-tissue (often better evaluated on MRI) and matrix mineralization (often better evaluated on CT).

There is no relevant literature regarding the specific use of CT with IV contrast or CT without and with IV contrast in the evaluation of suspected primary bone tumor with radiographs indeterminate for malignancy. However, if contrast is given, CT without and with IV contrast is preferred because it allows differentiation of areas of contrast enhancement from areas of osseous matrix production.

FDG-PET/CT Whole Body
FDG-PET has proven useful for further characterizing indeterminate bone tumors identified on radiographs. PET information can be co-registered with CT or MRI, taking advantage of the inherent benefits of these modalities. A number of studies have shown FDG-PET and FDG-PET/CT to be a valuable adjunct to conventional imaging in the diagnosis, staging, restaging, and surveillance of primary bone tumors [25-31]. Shin et al [32] evaluated the efficacy of FDG-PET/CT in differentiating benign from malignant pathologic fractures in a series of 34 patients. With a standardized uptake value max cut-off set at 4.7, they found the sensitivity, specificity, and diagnostic accuracy of FDG-PET/CT to be 89.5%, 86.7%, and 88.2%, respectively. However, it was noted that there may be significant overlap in the metabolic activity of benign and malignant lesions, such as those containing myxoid or necrotic components with inherent low metabolic activity. In a study of 29 patients assessing the value of PET in appropriately characterizing cartilage neoplasms, the overall sensitivity of PET in differentiating benign from malignant lesions was 90.9%, with a specificity of 100% and accuracy of 96.6% [33]. Bredella et al [26] found

that FDG-PET can help differentiate benign from malignant spinal compression fractures with a sensitivity of 86% and specificity of 83%; however, there was overlap in the range of standardized uptake value in the benign and malignant groups.

MRI Area of Interest

MRI is a robust tool that can further characterize an indeterminate bone lesion detected on radiographs. Despite its widespread use in this role, there are few controlled studies in the literature over the last 10 years specifically evaluating the role of MRI in further characterizing lesions detected on radiographs. Several studies do exist that serve to highlight the role of MRI in further characterizing the tissue composition (such as fat, hemorrhage, fluid levels) and anatomic extent of a variety of bone tumors [20-22,34,35]. MRI has also been shown to be useful in predicting the grade (benign versus malignant) of known primary bone tumors. A prospective study evaluating 200 consecutive bone tumors of the hand showed that MRI improved grading in comparison with radiography alone by correctly upgrading malignant tumors and downgrading benign tumors in 8% and 12% of cases, respectively [7]. Crim et al [9] performed a retrospective review of 53 cases of low-grade cartilage lesions (enchondroma and grade 1 chondrosarcoma) and found that MRI suggested the correct diagnosis of enchondroma in 57.8% of cases (radiographs correctly diagnosed 67.2% of cases) and the correct diagnosis of chondrosarcoma in 57.8% of cases (radiographs correctly diagnosed 20.8% of cases). Overall, MRI had an increased rate of both true-positive and false-positive diagnosis in comparison with radiographs. Similar to radiographic characterization, the characterization of low-grade chondroid lesions on MRI is challenging because of overlapping features of benign and malignant lesions.

MRI is generally considered the preferred imaging modality for staging of bone tumors [14]. Hogeboom et al [36] compared the value of MRI to CT in the evaluation of bone tumors in a prospective study of 25 patients. They found that MRI has better soft-tissue contrast than CT, making it possible to study the relationship of the bone tumor to the soft tissues, bone marrow, and joints more accurately. They found that CT better defines destruction of cortical bone. Specifically, MRI was superior to CT in detecting cortical bone destruction in 4.5% of patients studied and better at evaluating marrow involvement in 25%, soft-tissue involvement in 31%, joint involvement in 36.4%, and invasion of neurovascular structures in 15.3% of patients. MRI and CT were judged equivalent in these categories the majority of the time (ranging from 63% to 82% of the time for the various categories). CT was superior to MRI for some patients in two categories: detecting cortical bone destruction (13.6%) and neurovascular involvement (7.7%). If both modalities are available, the authors suggest that MRI is preferable to CT. A prospective study comparing the staging of primary bone sarcoma with CT, MRI, bone scintigraphy, and angiography in 56 patients showed that MRI was superior in defining tumor length, demonstrating involvement of muscle compartments, and delineating the relationship between tumor and major neurovascular bundles [37]. In the same study, MRI was shown to be comparable to CT in demonstrating cortical bone and joint involvement [37]. In contrast, results of a multi-institutional collaborative study assessing the relative accuracy of CT and MRI in the local staging of primary malignant musculoskeletal neoplasms showed no statistically significant difference between CT and MRI in determining tumor involvement of muscle, bone, joints, or neurovascular structures [23]. Furthermore, the combined interpretation of CT and MRI did not significantly improve accuracy [23]. However, a more recent retrospective study comparing the diagnostic accuracy of radiographs, CT, MRI, bone scintigraphy, and FDG-PET/CT versus pathology reports in 409 biopsy-proven tumors showed that the sensitivity of MRI and FDG-PET/CT was better than that of CT, bone scintigraphy, and radiographs. In spine lesions, MRI was the most sensitive modality for detection of tumors, followed by FDG-PET/CT and CT [38].

Several studies have shown that contrast-enhanced MRI and MR angiography can provide additional information (eg, more accurate characterization, evaluation of viability, and biopsy planning) for the preoperative evaluation of primary bone tumors [39-41]. In a study of 37 patients with cartilaginous tumors, Geirnaerdt et al [42] evaluated the utility of fast contrast-enhanced MRI in differentiating benign from malignant tumors. They found that differentiation of malignancy from benignity was possible with this technique, with a sensitivity of 61% and specificity of 95%. The usefulness of MRI with dynamic contrast enhancement in characterizing lesions as benign or malignant has been evaluated in several additional studies with mixed results [43,44]. Other imaging techniques, such as diffusion-weighted and chemical shift MRI, have been shown to be useful in differentiating benign from malignant bone tumors [45-47]. MRI with dynamic contrast enhancement [43], as well as diffusion and chemical shift MRI [47], can help differentiate benign from malignant spinal compression fractures. Characterization of bone tumors as benign or malignant with MR spectroscopy has shown promise in two small observational studies, although further research is needed [48,49].

Radiography Skeletal Survey
Radiographic survey of the whole body is of limited utility in the evaluation of a suspected primary bone tumor with an indeterminate or aggressive appearance detected on radiographs. The primary utility of radiographic skeletal survey is in evaluating the appearance and distribution of polyostotic bone lesions, which are most commonly multiple myeloma or metastases rather than primary bone lesions.

Bone Scan Whole Body
Despite its historical utility in further characterizing lesions detected on radiographs, there are no controlled studies in the literature over the last 10 years specifically evaluating the efficacy of bone scan in this role.

Bone Scan Whole Body with SPECT or SPECT/CT Area of Interest
Despite its historical utility in further characterizing lesions detected on radiographs, there are no controlled studies in the literature over the last 10 years specifically evaluating the efficacy of bone scan in this role. However, recent advances in technology, such as SPECT/CT, may provide a useful tool in the evaluation of primary bone tumors. A retrospective review of 99 patients with 108 vertebral lesions showed that SPECT/CT was superior to planar scintigraphy and SPECT alone, but not CT alone, in the characterization of indeterminate vertebral lesions found on bone scintigraphy [50].

US Area of Interest
US is not routinely used in the evaluation of indeterminate or aggressive bone lesions seen on radiographs. There is no relevant literature regarding the use of US in the evaluation of an indeterminate or aggressive lesion detected on radiographs.

Variant 6: "Incidental" osseous lesion on MRI or CT scan for unrelated indication. Suspect primary bone tumor. Not clearly benign. Next imaging study.

In situations in which lesions are incidentally found on advanced imaging studies and are considered indeterminate for malignancy, additional imaging examinations may be needed depending upon the findings and level of concern.

CT Area of Interest
There is no relevant literature regarding the use of CT in the evaluation of bone lesions incidentally found on MRI. However, CT, be it without IV contrast, with IV contrast, or without and with IV contrast, may provide complementary information, particularly in respect to assessing matrix mineralization, cortical destruction, or in suspected cases of osteoid osteoma. If contrast is given, CT without and with IV contrast is preferred because it allows differentiation of areas of contrast enhancement from areas of osseous matrix production. However, radiographic evaluation is generally recommended as the next best imaging modality.

FDG-PET/CT Whole Body
Radiographic evaluation is generally recommended as the next best imaging modality to evaluate bone lesions incidentally found on MRI and CT. FDG-PET/CT may play a limited role in the evaluation of bone lesions incidentally found on MRI and CT.

MRI Area of Interest
If the initial MRI is not of sufficient quality (eg, limited coverage, limited sequences, etc) or was performed using a nonmusculoskeletal protocol (eg, an incidentally discovered bone lesion on a prostate MRI), then a repeat MRI examination may be warranted. However, this should typically follow radiographic imaging, which can be used to better plan the repeat MRI. Supplementation of an MRI initially performed without IV contrast with contrast-enhanced sequences may provide additional information about lesion vascularity and relationship to regional vascular structures. MRI evaluation of the area of interest may provide complementary information facilitating further assessment of the lesion and can be helpful in preoperative planning.

Although there is no relevant literature regarding the use of MRI in the evaluation of bone lesions incidentally found on CT, MRI may provide complementary information, particularly with regard to evaluating soft-tissue components. However, radiographic evaluation is generally the next best imaging modality.

Radiography Area of Interest
Although there is no relevant literature specifically regarding recommendations for follow-up of bone lesions incidentally found on MRI, radiographic evaluation of the area of interest is generally considered the initial study of choice in this situation. Initial radiographs not only provide an accurate means by which to evaluate primary

bone tumors but also provide a baseline study for a bone lesion that may be followed radiographically. Radiographs provide information regarding tumor location, size, and shape as well as evidence of tumor biological activity [3]. Tumor margin and periosteal reaction provide a reliable index of biological potential of the tumor, whereas matrix, if identified, is a key to the underlying histology [3-6]. Although the utility of radiographs in stratifying bone lesions into aggressive and nonaggressive categories is well established, there is sparse literature documenting concrete values on accuracy. A prospective study evaluating 200 consecutive bone tumors of the hand showed that subjective grading of tumors based on radiographic features provided a correct categorization of tumor grade (benign versus malignant) in 82.5% of cases [7]. In a retrospective study applying a modified Lodwick-Madewell grading system to categorize 183 bone tumors, Caracciolo et al [8] found that a low radiographic grade assignment correlates with benignity and that increasing grade correlates with an increasing risk of malignancy. In the case of an incidental lesion on CT, radiographic evaluation of the area of interest may be helpful in allowing for assessment of the lesion based on well-established radiographic criteria. However, radiographs are unlikely to add any additional information specifically about matrix mineralization or cortical involvement that is not readily evident on CT. This is especially true if a high-quality CT with multiplanar reformatting in the coronal and sagittal planes was obtained.

Bone Scan Whole Body

Radiographic evaluation is generally recommended as the next best imaging modality to evaluate bone lesions incidentally found on MRI and CT. Bone scan may play a limited role in the evaluation of bone lesions incidentally found on MRI and CT.

US Area of Interest

There is no relevant literature regarding the use of US in the evaluation of bone lesions incidentally found on MRI or CT.

Summary of Recommendations

- **Variant 1**: Radiographs are usually appropriate for initial imaging of a suspected primary bone tumor.
- **Variant 2**: MRI without and with IV contrast or MRI without IV contrast is usually appropriate in patients with positive symptoms for a suspected primary bone tumor but negative radiographs. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 3**: MRI without and with IV contrast, MRI without IV contrast, or CT without IV contrast may be appropriate for evaluating suspected primary bone tumor with benign lesions on radiographs, which is not osteoid osteoma. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 4:** CT without IV contrast is usually appropriate for a suspected primary bone tumor in patients with radiographs or clinical presentations suggestive of osteoid osteoma. The panel did not agree on recommending CT without and with IV contrast in the evaluation of suspected osteoid osteoma because there is insufficient medical literature to conclude whether or not these patients would benefit from the procedure. CT without and with IV contrast in this patient population is controversial but may be appropriate.
- **Variant 5**: MRI without and with IV contrast is usually appropriate for a suspected primary bone tumor in patients with indeterminate or aggressive appearing lesions on radiographs that are suggestive for malignancy. The panel did not agree on recommending CT without and with IV contrast in the evaluation of indeterminate or aggressive bone lesions seen on radiographs because there is insufficient medical literature to conclude whether or not these patients would benefit from CT without and with IV contrast. CT without and with IV contrast in this patient population is controversial but may be appropriate.
- **Variant 6:** Radiographs are usually appropriate to evaluate bone lesions incidentally found and not clearly benign on MRI and CT. The panel did not agree on recommending CT without and with IV contrast in the evaluation of incidentally found bone lesions that are not clearly benign on CT and MRI because there is insufficient medical literature to conclude whether or not these patients would benefit from CT without and with IV contrast. CT without and 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 [51].

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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