

American College of Radiology ACR Appropriateness Criteria®

Clinical Condition: Primary Bone Tumors

Variant 1: Screening, first study.

Radiologic Procedure	Rating	Comments	RRL*
X-ray area of interest	9	Absolute requirement in patient with suspected bone lesion.	NS
US area of interest	1		O
MRI area of interest with or without contrast	1		O
Tc-99m bone scan whole body	1		☼ ☼ ☼
CT area of interest without contrast	1		NS
FDG-PET whole body	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: Persistent symptoms, but radiograph negative.

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest with or without contrast	9	Contrast may be useful, depends on expertise and institutional preference. See statement regarding contrast in text under “Anticipated Exceptions.”	O
Tc-99m bone scan whole body	4	Good option if patient cannot have MRI. Non specific. MRI more specific and sensitive.	☼ ☼ ☼
CT area of interest without contrast	3	If MRI not available. Useful to evaluate cortex and trabecular pattern.	NS
US area of interest	1		O
FDG-PET whole body	1		☼ ☼ ☼ ☼
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 3: Definitely benign on radiographs (Excluding osteoid osteoma).

Radiologic Procedure	Rating	Comments	RRL*
CT area of interest without contrast	4	The decision to do a CT depends on the size, location and type of “benign” lesion.	NS
US area of interest	1		O
MRI area of interest with or without contrast	1		O
Tc-99m bone scan whole body	1		☼ ☼ ☼
FDG-PET whole body	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:**Primary Bone Tumors****Variant 4:****Clinically suspected osteoid osteoma.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray area of interest	9	Necessary. Follow with CT if positive.	NS
CT area of interest without contrast	9		NS
Tc-99m bone scan whole body	6	Very sensitive but non-specific. Good for localization if lesion is occult radiographically.	☢ ☢ ☢
MRI area of interest with or without contrast	6	CT is more useful but diagnosis can often be made with MRI. Contrast may improve nidus identification. See statement regarding contrast in text under "Anticipated Exceptions."	O
US area of interest	1		O
FDG-PET whole body	1		☢ ☢ ☢ ☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 5:**Suspicious for malignant characteristics on radiograph.**

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest with or without contrast	9	Contrast can provide more information. Useful for vascularity and necrotic areas. See statement regarding contrast in text under "Anticipated Exceptions."	O
CT area of interest without contrast	5	May be useful if MRI not available or possible. Useful for evaluation of calcification, cortical breakthrough and pathological fractures.	NS
FDG-PET whole body	5	Can be useful for problem solving. See narrative.	☢ ☢ ☢ ☢
Tc-99m bone scan whole body	3	Probably not indicated, except to look for additional lesions.	☢ ☢ ☢
US area of interest	1		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

PRIMARY BONE TUMORS

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Summary of Literature Review

There are numerous imaging techniques for evaluating bone tumors. However, the routine radiograph remains the primary screening technique and is the least expensive for detection and histologic characterization of many tumors or tumor-like conditions of bone [1]. When a classically nonaggressive lesion is detected on routine radiographs, additional studies may not be required unless surgical intervention is contemplated and further anatomic information is required. In this setting either computed tomography (CT) or magnetic resonance imaging (MRI) may be most appropriate for preoperative evaluation [1-3].

Magnetic Resonance Imaging and Computed Tomography

When routine radiographic features are indeterminate or the lesion is more aggressive and considered to be potentially malignant, additional imaging studies are frequently required. In the past, radionuclide imaging was used to evaluate bone lesions in this setting. However, today, because of MRI's improved anatomic detail and sensitivity, it is preferred over radionuclide studies [4].

Early evaluation of MRI and CT demonstrated that MRI was superior for staging of bone tumors before treatment [1,3,5,6]. Zimmer et al [3] and Hogeboom et al [6] described MRI and CT features of bone tumors with regard to cortical destruction, marrow, soft-tissue, joint, and neurovascular involvement. Hogeboom et al [6] reported that MRI was superior to CT for cortical bone destruction in 4.5% of patients studied, for marrow involvement in 25%, for soft-tissue involvement in 31%, for joint involvement in 36.4%, and for invasion of neurovascular structures in 15.3%. In the same categories MRI and CT were felt to be equal in 63%-82% of patients. CT was superior to MRI for cortical bone destruction in 13.6% of patients and neurovascular involvement in 7.7% [6].

In most institutions the choice of imaging technique depends on patient status as well as the location and type of suspected lesion. MRI is most typically used for staging lesions in the extremities [1,3,5,7,8]. MR spectroscopy has potential to differentiate benign from malignant lesions, but more research is needed [9]. CT is usually preferred when tumors are located within the periosteal or cortical regions, with flat bones with thin cortex and little marrow, and to better demonstrate tumor mineralization, which may be suspected from routine radiographs [10]. For rib lesions, thin-section CT is useful to exclude fracture through a nonaggressive lesion [11]. CT is also preferred over MRI for detecting a characteristic central nidus in patients with suspected osteoid osteoma on radiographs [1,2,12,13].

Positron Emission Tomography

Positron emission tomography (PET) scanning has been used with success for detecting metabolically active metastatic lesions or recurrences and for preoperative evaluation of known sarcomas. PET has also shown promise in helping differentiate benign from malignant bone lesions [14-19]. However, although studies have found significant differences in the average SUVmax (maximum standard uptake value) between benign and malignant groups, there is significant overlap in individual tumor types, reflecting variegated metabolic activity in different lesions and complicating myxoid and necrotic components with low metabolic activity [14]. Studies have predominantly been performed on mixed lesion types, with low numbers of individual entities that could provide information regarding evaluation of specific tumor types for malignant potential. Bredella et al [15] have found that PET with fluorine-18-2-fluoro-2-deoxy-D-glucose tracer (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 SUV in the benign and malignant groups. Also, there have been reports of nontumor conditions (especially inflammatory entities) that can also result in abnormal uptake.

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The role of PET scanning in the workup of bone tumors has yet to be established. A lesion with indeterminate aggressiveness on radiographs with little to no increased uptake on PET scan could potentially undergo more conservative follow-up; however, more research is required in this regard. It seems clear that PET can provide more information, especially in patients who cannot undergo MRI and in situations where biopsy is not feasible due to location or patient condition. It can also be used to help plan biopsy, with PET/CT fusion images used to target areas with more cellular metabolic activity that may give higher diagnostic yield.

Ultrasound

While focused musculoskeletal ultrasound (US) with Doppler flow analysis can be a useful tool with some primary osseous and soft-tissue tumors, it is not considered a first-line modality. It should be considered when the size of the lesion renders imaging with pre-contrast-enhanced and post-contrast enhanced MRI incomplete, or when assessment of echotexture and vascularity might decrease the size of the differential after assessment with MRI and CT is complete. However, such an US assessment requires a skilled sonographer, and there is little in the medical literature describing differentiating characteristics of musculoskeletal tumors on US.

Chondroid Lesions

There are special considerations when dealing with suspected chondroid lesions. Intramedullary chondroid lesions appearing in the hands and feet are nearly always benign, and may present incidentally or as a pathological fracture. If the lesion is elsewhere it may be challenging for any imaging modality to differentiate a benign lesion from a low-grade malignancy. If there is pain related to the lesion, suspicion of malignancy should be high. Murphey et al [20] suggest that imaging features including deep endosteal scalloping, cortical destruction, soft-tissue mass (on CT or MRI), periosteal reaction (on radiographs), and marked uptake of radionuclide can be used to distinguish appendicular enchondroma from chondrosarcoma in at least 90% of cases. Geirnaerd et al [21] suggest that radiographic signs cannot discriminate reliably between enchondroma and grade 1 chondrosarcoma, but that axial location and large size (greater than 5 cm) are the most reliable predictors of malignancy in this setting. Geirnaerd et al [22] suggest that dynamic contrast-enhanced MRI can assist in differentiating benign from malignant chondroid lesions, and Feldman et al [23] suggest that PET may be useful; however, these modalities have not been clearly established for this purpose. Protocol for follow-up of an asymptomatic, incidentally identified lesion has not been scientifically established. Authors such as Mirra's group [24] suggest that the risk of malignant transformation is increased for larger lesions, lesions in the axial skeleton, and in the setting of multiple lesions (eg, Ollier's disease). They suggest radiographic follow-up for those with higher risk but stop short of making specific

recommendations regarding interval and extent of follow-up.

Other Imaging Modalities

Patients with symptoms related to the bone or joint with normal radiographs present a different problem. Though CT may be performed in this setting, a radionuclide bone scan may be more useful to localize the abnormality [2,13]. MRI can be very useful in this setting not only to identify whether a lesion is present but also to define the nature of a lesion based on the features discussed above; as a result, MRI is generally preferred. If an osteoid osteoma is suspected, Assoun et al [2] reported that CT was more accurate than MRI in 63% of cases. However, Liu et al [25] reported that dynamic contrast-enhanced MRI can improve conspicuity of osteoid osteoma compared to CT.

Other invasive imaging techniques, such as angiography, are not commonly required. Weatherall et al [26] compared MRI, CT, technetium-99m bone scans, and angiography for local staging of 56 patients with primary bone sarcomas. This study demonstrated that MRI was superior to CT and scintigraphy in defining the extent of bone involvement and was equal in accuracy to CT in demonstrating joint and cortical involvement. CT, MRI, and angiography were compared for evaluating neurovascular involvement. CT demonstrated a sensitivity of 33%, MRI 100%, and angiography 83% with specificities of 93% for CT, 98% for MRI, and 71% for angiography. This study concluded that MRI is the technique of choice for evaluating and staging primary bone sarcomas, including neurovascular involvement. MRI is useful for determining tissue characteristics of a bone lesion, such as fat, hemorrhage, fibrous tissue, or fluid levels. With gadolinium contrast, cystic or necrotic areas can be detected [8,27-29].

Summary

- Routine radiographs remain the optimal screening technique for primary bone tumors.
- When lesions are characteristically nonaggressive, additional imaging may not be required unless needed for preoperative planning. The data suggest that MRI is the preferred technique for staging of primary bone neoplasms but in some categories CT is equal or superior to MRI.
- CT is preferred for patients with suspected osteoid osteoma or subtle cortical abnormalities, and for evaluating matrix mineralization.
- Advanced imaging modalities provide complementary information, and often more than one is required for diagnostic or preprocedure evaluation.

Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the

administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (ie, <30 mL/min/1.73m²), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73m². For more information, please see the [ACR Manual on Contrast Media](#) [30].

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
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 NS (not specified).

Supporting Document(s)

- [ACR Appropriateness Criteria[®] Overview](#)
- [Procedure Information](#)
- [Evidence Table](#)

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