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	This procedure is absolutely required in a patient with suspected bone lesion.	Varies
US area of interest	1		O
MRI area of interest without and with IV contrast	1		O
MRI area of interest without IV contrast	1		O
Tc-99m bone scan whole body	1		☢ ☢ ☢
CT area of interest without IV contrast	1		Varies
CT area of interest with IV contrast	1		Varies
CT area of interest without and with IV contrast	1		Varies
FDG-PET/CT 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: **Positive localized or regional symptoms. Radiographs negative or findings do not explain symptoms.**

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest without IV contrast	9		O
MRI area of interest without and with IV contrast	7		O
Tc-99m bone scan whole body	5	Perform this procedure if better localization is needed.	☢ ☢ ☢
CT area of interest without IV contrast	5	This procedure may be useful for certain types of tumors.	Varies
CT area of interest with IV contrast	1		Varies
CT area of interest without and with IV contrast	1		Varies
US area of interest	1		O
FDG-PET/CT 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 3: **Lesion on radiographs definitively benign. Not osteoid osteoma.**

Radiologic Procedure	Rating	Comments	RRL*
CT area of interest without IV contrast	4	Perform this procedure if the patient is symptomatic locally.	Varies
MRI area of interest without IV contrast	4	Perform this procedure if the patient is symptomatic locally.	O
CT area of interest with IV contrast	1		Varies
CT area of interest without and with IV contrast	1		Varies
US area of interest	1		O
MRI area of interest without and with IV contrast	1		O
Tc-99m bone scan whole body	1		☢ ☢ ☢
FDG-PET/CT 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 4: **Lesion on radiographs. Radiographic and/or clinical pattern suspicious for osteoid osteoma.**

Radiologic Procedure	Rating	Comments	RRL*
CT area of interest without IV contrast	9		Varies
MRI area of interest without and with IV contrast	6	Dynamic contrast enhancement may be valuable in this procedure.	O
MRI area of interest without IV contrast	5		O
Tc-99m bone scan whole body	4	SPECT might be useful as an adjunct to this procedure.	☢ ☢ ☢
CT area of interest with IV contrast	1		Varies
CT area of interest without and with IV contrast	1		Varies
US area of interest	1		O
FDG-PET/CT 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 5: **Lesion on radiographs. Indeterminate for malignancy with mineralized matrix.**

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest without and with IV contrast	8		O
MRI area of interest without IV contrast	7		O
CT area of interest without IV contrast	7		Varies
Tc-99m bone scan whole body	5	This procedure may be helpful when evaluating for disease distribution or other areas of involvement.	☢ ☢ ☢
FDG-PET/CT whole body	3		☢ ☢ ☢ ☢
CT area of interest without and with IV contrast	2		Varies
CT area of interest with IV contrast	1		Varies
US area of interest	1		O
X-ray skeletal survey	1		☢ ☢ ☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Variant 6: **Lesion on radiographs. Indeterminate for malignancy. Lytic lesion.**

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest without and with IV contrast	8		O
MRI area of interest without IV contrast	7		O
CT area of interest without IV contrast	7		Varies
X-ray skeletal survey	5	Perform this procedure if there is concern that the lesion represents multiple myeloma.	☢ ☢ ☢
Tc-99m bone scan whole body	5	This procedure may be helpful when evaluating for disease distribution or other areas of involvement.	☢ ☢ ☢
CT area of interest without and with IV contrast	4	Perform this procedure if MRI is contraindicated.	Varies
FDG-PET/CT whole body	3		☢ ☢ ☢ ☢
CT area of interest with IV contrast	2		Varies
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**

Clinical Condition: **Primary Bone Tumors**

Variant 7: **Lesion on radiographs. Indeterminate for malignancy. Sclerotic or mixed lytic/sclerotic lesion.**

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest without and with IV contrast	8		O
MRI area of interest without IV contrast	7		O
CT area of interest without IV contrast	7		Varies
Tc-99m bone scan whole body	5		☢ ☢ ☢
CT area of interest without and with IV contrast	4	Perform this procedure if MRI is contraindicated.	Varies
FDG-PET/CT whole body	3		☢ ☢ ☢ ☢
X-ray skeletal survey	2		☢ ☢ ☢
CT area of interest with IV contrast	2		Varies
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**

Variant 8: **Lesion on radiographs. Aggressive, suspicious for malignancy.**

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest without and with IV contrast	9		O
MRI area of interest without IV contrast	8		O
CT area of interest without IV contrast	7	This procedure is especially useful for areas with complex osseous anatomy.	Varies
Tc-99m bone scan whole body	6	This procedure is particularly helpful to look for multifocal disease.	☢ ☢ ☢
X-ray skeletal survey	5	Perform this procedure if there is concern that the lesion represents multiple myeloma.	☢ ☢ ☢
CT area of interest without and with IV contrast	5	Perform this procedure if MRI is contraindicated.	Varies
FDG-PET/CT whole body	5	This procedure is particularly helpful to look for multifocal disease.	☢ ☢ ☢ ☢
CT area of interest with IV contrast	2		Varies
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**

Clinical Condition: **Primary Bone Tumors**

Variant 9: **Lesion with pathological fracture on radiographs. Not definitively benign.**

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest without and with IV contrast	8		O
MRI area of interest without IV contrast	7		O
CT area of interest without IV contrast	5		Varies
Tc-99m bone scan whole body	5	This procedure is particularly helpful to look for multifocal disease.	☢ ☢ ☢
CT area of interest without and with IV contrast	4	Perform this procedure if MRI is contraindicated.	Varies
FDG-PET/CT whole body	4		☢ ☢ ☢ ☢
CT area of interest with IV contrast	2		Varies
US area of interest	1		O
X-ray skeletal survey	1		☢ ☢ ☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Variant 10: **No radiographs. "Incidental" finding on MRI. Not clearly benign.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray area of interest	9		Varies
MRI area of interest without and with IV contrast	5	Use of this procedure depends on size and location in addition to sequences and field of view on original MRI.	O
MRI area of interest without IV contrast	5	Use of this procedure depends on size and location in addition to sequences and field of view on original MRI.	O
CT area of interest without IV contrast	5		Varies
FDG-PET/CT whole body	2		☢ ☢ ☢ ☢
CT area of interest with IV contrast	1		Varies
CT area of interest without and with IV contrast	1		Varies
Tc-99m bone scan whole body	1		☢ ☢ ☢
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**

Clinical Condition: **Primary Bone Tumors**

Variant 11: **No radiographs. "Incidental" finding on CT. Not clearly benign.**

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest without IV contrast	9		O
MRI area of interest without and with IV contrast	7		O
X-ray area of interest	5	Use of this procedure depends on size and location in addition to adequacy of initial CT evaluation.	Varies
Tc-99m bone scan whole body	4		☢ ☢ ☢
CT area of interest without IV contrast	3	Use of this procedure depends on the quality of the original CT. A focused study may be helpful in some cases.	Varies
CT area of interest with IV contrast	1		Varies
CT area of interest without and with IV contrast	1		Varies
FDG-PET/CT whole body	1		☢ ☢ ☢ ☢
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

Introduction/Background

Numerous imaging techniques are available for evaluating bone tumors. However, radiographs remain the primary screening technique and are the least expensive methods of detecting and histologically characterizing 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 additional characterization and preoperative evaluation [1-3].

Magnetic Resonance Imaging and Computed Tomography

When 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 the improved anatomic detail and sensitivity of MRI, 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 in detecting 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 in detecting cortical bone destruction in 13.6% of patients and neurovascular involvement in 7.7% [6]. However, Panicek et al [7] more recently showed no difference between CT and MRI for evaluation of extent of tumor involvement in 183 patients with primary bone tumors, suggesting that both are equally accurate for staging purposes. Comparison studies are not recent, and evolution of technology may limit relevance of these data.

In most institutions the 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 [1,3,5,8,9]. Intravenous contrast dye can be useful to determine vascularity of lesions [10-12], detect vascular invasion [13], and identify necrotic or cystic areas. MR spectroscopy has potential to differentiate benign from malignant lesions, but more research is needed [14,15]. CT is usually preferred when tumors are located within the periosteal or cortical regions, with flat bones with thin cortex and little marrow, as well as in small bones such as those in the hands and feet, in which case higher resolution can be advantageous. CT can better demonstrate tumor mineralization, which may be suspected or indeterminate on radiographs [16]. CT may also be preferred in certain circumstances where characterization of osseous anatomy and proximity to other structures is paramount, including pelvis and spine. For rib lesions, thin-section CT is useful to exclude fracture through a nonaggressive lesion [17] or to differentiate traumatic versus

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pathological fracture. CT is also preferred over MRI for detecting a characteristic central nidus in patients with suspected osteoid osteoma on radiographs [1,2,18,19].

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. Data can be co-registered with CT or MRI to correlate with anatomic information. PET has shown promise in helping differentiate benign from malignant bone lesions [20-25]. However, although studies have found significant differences in the average maximum standard uptake value (SUV_{max}) 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 [20]. Studies have predominantly been performed on mixed lesion types, with few individual entities that could provide information regarding evaluation of specific tumor types for malignant potential. Bredella et al [21] 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.

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

Although 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 complete assessment with MRI and CT. However, such a US assessment requires a skilled sonographer, and there is little in the medical literature describing differentiating characteristics of musculoskeletal tumors on US.

Angiography

Angiography is not generally indicated except in specialized individual circumstances. Information from invasive diagnostic procedures (except biopsy) has been effectively replaced by noninvasive advanced imaging techniques.

Evaluation of Lytic Lesions Versus Lesions With Sclerotic Features

Lesions seen on radiographs may require additional characterization using advanced imaging examinations; the next appropriate examination may depend on the nature of the lesion: lytic versus sclerotic. For example, a purely lytic lesion may need to be further characterized as solid or cystic not only to narrow the differential diagnosis but also to help guide treatment and biopsy planning (ie, to avoid necrotic or myxoid areas). In this case MRI may be most useful. For mixed lytic/sclerotic or sclerotic lesions there may be matrix mineralization better characterized on CT. Or, if purely sclerotic the differential may be a bone island versus an osteoblastic tumor, in which case a bone scan may be the most useful test.

Chondroid Lesions

There are special considerations when dealing with a suspected chondroid lesion. 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 to differentiate a benign lesion from a low-grade malignancy using any imaging modality. If there is pain related to the lesion, suspicion of malignancy should be high. However, care should be taken to exclude adjacent joint pathology as the source of pain, which may require advanced imaging. A study of 57 patients presenting to an orthopedic oncologist with shoulder pain and a cartilage tumor showed that 82% had shoulder imaging findings that could explain the pain [26]. Once other etiologies for the pain have been excluded, some radiologic findings have been useful in differentiating benign and malignant lesions. Murphey et al [27] 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. However, Bui et al [28] suggest that endosteal scalloping is seen in benign lesions. Geirnaerdt et al [29] suggest that radiographic signs cannot discriminate reliably between enchondroma and grade 1 chondrosarcoma, but axial location and large size (greater than 5 cm) are the most reliable predictors of malignancy in this setting. Geirnaerdt et al [30] suggest that dynamic contrast-enhanced MRI can assist in differentiating benign from malignant chondroid lesions, and Feldman et al [31] 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. Brien and others [32] suggest that the risk of malignant transformation is increased for larger lesions and lesions in the axial skeleton and in the setting of multiple lesions (eg, Ollier disease). They suggest radiographic follow-up for those at higher risk but do not make specific recommendations regarding interval and extent of follow-up.

Lesion Presenting With Pathological Fracture

Benign and malignant lesions can present with pathological fracture. Especially if imaging is delayed, hemorrhage and bone resorption can lead to a more aggressive appearance, making it difficult to assess for benign characteristics. Early imaging is essential to limit this detrimental effect. In this case, MRI can best evaluate for presence of an underlying lesion.

"Incidental Lesions" Found on CT or MRI

On other occasions lesions are incidentally found on advanced imaging studies and are indeterminate for malignancy. Other imaging examinations may be needed depending upon the findings and level of concern (ie, history of cancer elsewhere). Radiographs are generally indicated for a lesion found on MRI, but a lesion suspected on CT may require an MRI or bone scan for further characterization.

Symptoms With Negative Radiographs

There is a wide differential for symptomatic patients who either have negative radiographs or have radiographs with findings that do not explain the pain. This includes injury such as stress fracture, early infection, or radiographically occult tumor. In any case, advanced imaging may be required based on history and degree of clinical concern. In this situation the referring physician should not be confident that there is no pathology if the radiographic result is negative or nonspecific; radiographs are often insensitive, especially in early disease.

Although CT may be performed in this setting, a radionuclide bone scan may be more useful to localize the abnormality [2,19]. 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 [33] reported that dynamic contrast-enhanced MRI can improve conspicuity of osteoid osteoma compared to CT. 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 [9,34-37].

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 CT is equal or superior to MRI in some categories.
- 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 modality is required for diagnostic or preprocedure evaluation.

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 "Varies".		

Supporting Documents

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

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