American College of Radiology
ACR Appropriateness Criteria®
Malignant or Aggressive Primary Musculoskeletal Tumor-Staging And Surveillance

Variant 1: **Malignant or aggressive primary musculoskeletal tumor. Initial staging. Evaluation for pulmonary metastasis.**

Procedure	Appropriateness Category	Relative Radiation Level
CT chest without IV contrast	Usually Appropriate	☢☢☢
FDG-PET/CT whole body	May Be Appropriate	☢☢☢☢
Radiography chest	Usually Not Appropriate	☢
CT chest with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢
FDG-PET/MRI whole body	Usually Not Appropriate	☢☢☢

Variant 2: **Malignant or aggressive primary musculoskeletal tumor. Initial staging. Evaluation for extrapulmonary metastasis.**

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

Variant 3: **Malignant or aggressive primary musculoskeletal tumor with no suspected or known recurrence. Surveillance for pulmonary metastasis.**

Procedure	Appropriateness Category	Relative Radiation Level
CT chest without IV contrast	Usually Appropriate	☢☢☢
FDG-PET/CT whole body	May Be Appropriate	☢☢☢☢
Radiography chest	Usually Not Appropriate	☢
CT chest with IV contrast	Usually Not Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢
FDG-PET/MRI whole body	Usually Not Appropriate	☢☢☢

Variant 4: **Malignant or aggressive primary bone tumor. Surveillance for local recurrence.**

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

Variant 5: **Malignant or aggressive primary soft tissue tumor. Surveillance for local recurrence.**

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
US area of interest	May Be Appropriate (Disagreement)	O
FDG-PET/MRI whole body	May Be Appropriate	☢☢☢
FDG-PET/CT whole body	May Be Appropriate	☢☢☢☢
CT area of interest with IV contrast	May Be Appropriate	Varies
Radiography area of interest	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

MALIGNANT OR AGGRESSIVE PRIMARY MUSCULOSKELETAL TUMOR-STAGING AND SURVEILLANCE

Expert Panel on Musculoskeletal Imaging: Rupert Stanborough, MD[a]; Jennifer L. Demertzis, MD[b]; Daniel E. Wessell, MD, PhD[c]; Leon Lenchik, MD[d]; Shivani Ahlawat, MD[e]; Jonathan C. Baker, MD[f]; James Banks, MD[g]; Jamie T. Caracciolo, MD, MBA[h]; Hillary W. Garner, MD[i]; Courtney Hentz, MD[j]; Valerae O. Lewis, MD[k]; Yi Lu, MD, PhD[l]; Jennifer R. Maynard, MD[m]; Jennifer L. Pierce, MD[n]; Jinel A. Scott, MD, MBA[o]; Akash Sharma, MD, MBA[p]; Francesca D. Beaman, MD.[q]

Summary of Literature Review

Introduction/Background

The terms "bone tumor" and "soft tissue tumor" have broad definitions. Many of these tumors do not conform to a binary benign or malignant assignment. The World Health Organization (WHO) classifies bone and soft tissue tumors into benign, intermediate locally aggressive, intermediate locally aggressive rarely metastasizing, and malignant categories [1]. For this reason, this document pertains to both malignant tumors and those intermediate or "aggressive" tumors of bone and soft tissue origin. Malignant and aggressive primary bone and soft tissue tumors of musculoskeletal origin are rare. In 2020, soft tissue tumors represented 0.7% and bone/joint tumors 0.2% of all new cancer cases in the United States [2,3]. The WHO recognizes more than 50 histologic subtypes of soft tissue tumors and over 30 subtypes of bone tumors. Many publications addressing staging and surveillance of these tumors are statistically underpowered given the rarity of bone and soft tissue tumors. Additionally, much of the literature is historic and outcomes have changed with more recent therapeutic and imaging advances. Most of these tumors are referred to and treated at tertiary medical centers, where the available medical evidence is supplemented by clinical experience and expert opinion to formulate a treatment plan. The authors have attempted to consolidate this diverse group of tumors as much as possible to simplify the application of these recommendations. Variation in applying these recommendations is expected and encouraged on an individual basis with particular attention to tumor histology and grading.

This document is specific to malignant or aggressive primary tumors of bone or soft tissue origin. This document specifically does not pertain to 1) metastatic disease to bone or soft tissues, 2) primary tumors of spine or neuroaxis origin, 3) primary tumors of head or neck origin, 4) intraabdominal or retroperitoneal tumors, 5) primary tumors of skin origin, and 6) plasma cell or other hematologic disorders that involve bone (ie, multiple myeloma). The variants in this document assume a diagnosis of a primary malignant or aggressive bone or soft tissue tumor has already been established. This document does not address the evaluation of chemotherapy or radiation therapy effectiveness or issues of cost-effectiveness and radiation dose.

Special Imaging Considerations

Hardware reconstruction is often needed following limb-sparing surgery for the management of bone tumors and occasionally for soft tissue tumors. This hardware creates artifact and limits evaluation of the adjacent structures with traditional CT, PET/CT, and MRI sequences and techniques. Although metal artifact can negatively impact CT, PET/CT, and/or MRI image quality, this document assumes metal artifact can be minimized with current metal artifact reduction protocols. There may still be instances where metal artifact cannot be sufficiently suppressed, and CT, PET/CT, and/or MRI become of limited benefit. In these cases, deviations from the variant recommendations may be necessary and should be informed by the clinical experience and expertise of the treatment team.

[a]Research Author, Mayo Clinic Florida, Jacksonville, Florida. [b]Diagnostic Imaging Associates, Chesterfield, Missouri. [c]Panel Chair, Mayo Clinic, Jacksonville, Florida. [d]Panel Vice-Chair, Wake Forest University School of Medicine, Winston Salem, North Carolina. [e]The Johns Hopkins University School of Medicine, Baltimore, Maryland. [f]Mallinckrodt Institute of Radiology Washington University School of Medicine, Saint Louis, Missouri. [g]Nova Southeastern University, Fort Lauderdale, Florida. [h]Moffitt Cancer Center and University of South Florida Morsani College of Medicine, Tampa, Florida; MSK-RADS (Bone) Committee. [i]Mayo Clinic Florida, Jacksonville, Florida. [j]Stritch School of Medicine Loyola University Chicago, Maywood, Illinois; Commission on Radiation Oncology. [k]University of Texas Health Science Center, Houston, Texas; American Academy of Orthopaedic Surgeons. [l]Brigham & Women's Hospital & Harvard Medical School, Boston, Massachusetts; American Association of Neurological Surgeons/Congress of Neurological Surgeons. [m]Mayo Clinic Florida, Jacksonville, Florida, Primary care physician. [n]University of Virginia, Charlottesville, Virginia. [o]SUNY Downstate Health Sciences University, Brooklyn, New York. [p]Mayo Clinic, Jacksonville, Florida; Commission on Nuclear Medicine and Molecular Imaging. [q]Specialty Chair, University of Kentucky, Lexington, Kentucky.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through representation of such organizations on expert panels. Participation on the expert panel does not necessarily imply endorsement of the final document by individual contributors or their respective organization.

Reprint requests to: publications@acr.org

Discussion of Procedures by Variant

Variant 1: Malignant or aggressive primary musculoskeletal tumor. Initial staging. Evaluation for pulmonary metastasis.

Approximately 20% of patients with primary extremity sarcomas will have or develop distant metastatic disease. Pulmonary metastases account for approximately 75% of all sarcoma metastases, with variations of incidence depending on tumor histology and grade [4,5]. Metastatic disease decreases survival, with pulmonary metastases as the primary cause of death in patients with osteosarcoma [6,7]. Metastasectomy improves survival, and thermal ablation and radiation therapy are emerging as promising alternative treatment options [8-10]. Therefore, evaluation for pulmonary metastases is an essential part of primary musculoskeletal tumor initial staging.

CT Chest With IV Contrast

There is no relevant literature regarding the specific use of CT chest with intravenous (IV) contrast in the evaluation of pulmonary metastasis from malignant or aggressive primary musculoskeletal tumors. However, IV contrast may lead to equivocal assessment of mineralization, which can be a useful morphologic feature to distinguish benign versus malignant pulmonary nodules. Therefore, CT chest with IV contrast is not generally useful as the sole imaging technique, and there is felt to be little additional benefit in the CT assessment of pulmonary nodules without and with IV contrast compared with CT chest without IV contrast in this setting.

CT Chest Without and With IV Contrast

There is no relevant literature regarding the specific use of CT chest without and with IV contrast in the evaluation of pulmonary metastasis from malignant or aggressive primary musculoskeletal tumors. However, IV contrast may lead to equivocal assessment of mineralization, which can be a useful morphologic feature to distinguish benign versus malignant pulmonary nodules. Therefore, CT chest with IV contrast is not generally useful as the sole imaging technique, and there is felt to be little additional benefit in the CT assessment of pulmonary nodules without and with IV contrast compared with CT chest without IV contrast in this setting.

CT Chest Without IV Contrast

CT chest is the most sensitive imaging modality for identifying pulmonary nodules compared with radiography, fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT, or FDG-PET/MRI. However, studies have shown that even CT underestimates the number of pulmonary metastases compared with lung palpation during thoracotomy. Specific to osteosarcoma pulmonary metastases, CT missed approximately 10% of palpable lung lesions, of which nearly half were confirmed metastases in a series of 118 patients with osteosarcoma [9]. A smaller series of 28 patients with osteosarcoma also showed that CT missed 26% of viable metastases compared with palpation [11]. However, as CT technology improves and slice thickness decreases, more and smaller pulmonary nodules can be identified resulting in the dilemma of increased false-positive rates. A study of 283 lung nodules in patients with osteosarcoma found a statistically significant cutoff of 6 mm to differentiate benign and malignant pulmonary nodules (specificity 89.8%) [9]. A study of 311 subcentimeter pulmonary nodules in 195 patients with soft tissue sarcoma found combining morphologic criteria, in addition to size criteria, helped differentiate benign and malignant pulmonary nodules, with round solid nodules >5 mm more likely to be malignant (76% $P = .002$) and complex ground-glass nodules <5 mm more likely to be benign (84%, $P < .0001$) [12]. Given the survival benefit of treating pulmonary metastases, if pulmonary nodules are identified on any other modality in patients with primary musculoskeletal sarcoma, CT chest is then often indicated for biopsy and/or pretreatment planning.

FDG-PET/CT Whole Body

A meta-analysis of FDG-PET/CT for the staging of patients with osteosarcoma demonstrated 81% combined sensitivity and 94% specificity for detection of lung metastases [6]. The superiority of PET when combined with CT has been established [13]. Comparison studies between PET imaging alone versus CT acquired during FDG-PET/CT have been reported, although the CT acquired for attenuation correction and anatomic registration is not regarded as equivalent to dedicated diagnostic CT chest imaging [13]. Roberge et al [14] compared FDG-PET/CT with conventional imaging in a cohort of 109 patients during staging of extremity and body wall soft tissue sarcomas. In this cohort, 16 of the 109 patients had lung metastases, 10 of which were only identified on CT chest. Only 1 of the 16 patients with lung metastases was identified with FDG-PET/CT imaging but not CT chest. The authors concluded that FDG-PET/CT added little benefit over CT chest alone in evaluating for pulmonary metastasis [14].

A study comparing staging and follow-up imaging studies in 41 children with primary bone sarcomas showed greater sensitivity of CT chest (93%) versus FDG-PET/CT (80%) in detecting pulmonary metastases (although

specificity was higher with FDG-PET/CT at 96% compared with 87% for CT chest). Of the false-negative FDG-PET/CT results in that study, half were pulmonary nodules <10 mm [15]. Evaluation of subcentimeter pulmonary nodules is a known limitation of FDG-PET/CT because of the inherent resolution constraints of PET/CT technology and respiratory motion artifact. However, a study of 63 lung nodules in 18 pediatric patients with bone sarcoma did demonstrate the value of using an FDG-PET standardized uptake value (SUV) cutoff in evaluating small pulmonary nodules; using an SUV_{max} >1 cutoff value and a nodule diameter cutoff of 6 mm can differentiate benign and malignant nodules with an accuracy of 92.1% compared with an accuracy of 88.9% with FDG-PET/CT visual analysis alone [16].

FDG-PET/MRI Whole Body

Literature specific to sarcoma staging with FDG-PET/MRI is scarce. A single study by Platzek et al [17] in 2017 evaluated FDG-PET/MRI in sarcoma staging in 29 patients and compared results with conventional CT or MRI studies. Eight of the 29 patients had lung metastases, which were identified on both the FDG-PET/MRI and conventional imaging. However, the small sample size precludes application of this data to larger populations. The inherent decreased spatial resolution of MRI compared to CT raises doubts about the ability to identify small pulmonary metastases with FDG-PET/MRI as accurately as CT. MRI of the lungs relies heavily on the ability to minimize respiratory motion.

Radiography Chest

There is no relevant literature to support the use of chest radiography in the evaluation of pulmonary metastases in the initial staging of malignant or aggressive primary musculoskeletal tumors.

Variant 2: Malignant or aggressive primary musculoskeletal tumor. Initial staging. Evaluation for extrapulmonary metastasis.

The body regions covered in this clinical scenario are ankle, chest, shoulder, elbow, femur, foot, forearm, hand, humerus, knee, pelvis, tibia/fibula, and wrist.

Extrapulmonary metastases are less common than pulmonary metastases in patients with primary extremity sarcomas [5]. Rates and locations for extrapulmonary metastases vary depending on tumor histology and grade; specifically, myxoid liposarcoma and alveolar rhabdomyosarcoma commonly present with extrapulmonary metastases [18-20]. Metastatic disease portends a poorer prognosis, and in cases of Ewing sarcoma, osseous metastasis rather than pulmonary metastasis is associated with decreased survival [21,22]. The identification of metastatic disease increases tumor stage and changes management. Surveillance for extrapulmonary metastases is usually not supported in asymptomatic patients with malignant or aggressive musculoskeletal tumors. When recurrence has been established, evaluation or “restaging” for extrapulmonary metastases is essentially the same as the initial staging discussed in this variant.

Bone Scan Whole Body

Although historically Tc-99m bone scan has been used to detect bone metastasis, more recent studies have shown Tc-99m bone scan is inferior to FDG-PET/CT in the detection of bone metastases in general oncologic populations [23]. This conclusion has also been supported in patients with bone sarcoma. A study of 206 patients with stage IV osteosarcoma who underwent both Tc-99m bone scan and FDG-PET/CT calculated a 95% sensitivity and 98% accuracy for FDG-PET/CT versus 76% and 96%, respectively, for Tc-99m bone scan [24]. A smaller study of 64 pediatric patients with bone sarcoma also showed greater accuracy of FDG-PET/CT (84%) versus Tc-99m bone scan (70%) in detecting bone metastases during initial staging [22]. Other studies have suggested that this FDG-PET/CT superiority may be specific only to osteolytic metastases but not osteoblastic metastases [25-27]. The ability to detect extraosseous metastases that are usually occult on Tc-99m bone scan is an additional benefit of FDG-PET/CT [28].

Similarly, studies have demonstrated MRI whole body is superior to Tc-99m bone scan in detecting bone metastases in general populations. A study specific to patients with Ewing sarcoma of bone that had both MRI whole body and Tc-99m bone scan showed not only more bone metastases were identified with MRI, but 4 of the 71 patients had bone metastases only detected on MRI which changed the tumor stage for these patients [29].

Bone Scan Whole Body with SPECT or SPECT/CT Area of Interest

The addition of single-photon emission computed tomography (SPECT) and SPECT/CT to Tc-99m bone scans can increase diagnostic confidence. A study of 2,954 Tc-99m bone scans in a general oncologic population increased diagnostic confidence by 75% and reduced equivocal findings by 27% [30]. However, there is no relevant literature

to support the specific use of SPECT or SPECT/CT with bone scans in the initial staging for extrapulmonary metastasis of malignant or aggressive musculoskeletal tumors.

CT Area of Interest With IV Contrast
CT can be used to evaluate an area of interest identified clinically or from another imaging modality. There is no relevant literature to support the use of localized CT at an area of interest in the initial staging for extrapulmonary metastasis of malignant or aggressive musculoskeletal tumors; rather, a systemic approach to initial staging is recommended.

CT Area of Interest Without and With IV Contrast
CT can be used to evaluate an area of interest identified clinically or from another imaging modality. There is no relevant literature to support the use of localized CT at an area of interest in the initial staging for extrapulmonary metastasis of malignant or aggressive musculoskeletal tumors; rather, a systemic approach to initial staging is recommended.

CT Area of Interest Without IV Contrast
CT can be used to evaluate an area of interest identified clinically or from another imaging modality. There is no relevant literature to support the use of localized CT at an area of interest in the initial staging for extrapulmonary metastasis of malignant or aggressive musculoskeletal tumors; rather, a systemic approach to initial staging is recommended.

FDG-PET/CT Whole Body
A meta-analysis of FDG-PET/CT for the staging of patients with osteosarcoma demonstrated an overall sensitivity of 93% and a specificity of 97% for detection of bone metastases [6]. Coverage of a whole body FDG-PET/CT varies and usually extends either from skull base to thighs or skull vertex to feet. A study of FDG-PET/CT in patients with sarcoma and melanoma showed inclusion of the entire lower extremities does not add additional benefit in identifying metastases [31].

FDG-PET/CT is considered superior to Tc-99m bone scan in the detection of osseous metastases. Literature has concluded this in both general oncologic and bone sarcoma populations [30]. FDG-PET/CT is also superior to CT imaging in this regard. Quartuccio et al [22] studied 64 pediatric patients with bone sarcoma and found greater accuracy of FDG-PET/CT (85% accuracy) versus CT (44% accuracy) in detecting bone metastases during initial staging of patients with Ewing sarcoma. There are mixed conclusions when comparing FDG-PET/CT versus MRI whole body in detecting osseous metastases in general oncology populations [32-34]. In a small study of 20 patients with Ewing sarcoma comparing FDG-PET/CT with MRI whole body, a single patient had a false-positive bone finding on FDG-PET/CT. Overall, 39% more bone lesions in this study were identified with MRI whole body versus FDG-PET/CT [35]. In the Quartuccio et al [22] study of 64 pediatric patients with bone sarcoma, when FDG-PET/CT was compared with MRI for the detection of bone metastases, accuracy was similar (85% versus 89%). MRI better discriminates bone metastases from hematopoietic marrow, both of which can have increased metabolic activity on PET imaging. An advantage of PET over MRI is the ability to quantify tumor metabolic activity, which can serve as a prognostic indicator [15].

FDG-PET/CT can also be useful to detect nonskeletal metastases, more frequently in the lung, but also lymph nodes and other organs. FDG-PET/CT can detect a greater number of nodal metastases in soft tissue sarcoma versus conventional imaging alone [36,37]. The incidence of nodal metastases is dependent on tumor histology.

FDG-PET/MRI Whole Body
Literature specific to sarcoma staging with FDG-PET/MRI is scarce. A study of 29 patients with sarcoma who underwent FDG-PET/MRI and conventional imaging (CT chest/abdomen and/or local MRI) showed no significant difference in accuracy for detecting metastases with sensitivities and specificities of 97.8% and 100% for FDG-PET/MRI compared with 94.4% and 100% for conventional imaging. Of the 10 patients in this study with metastases, 6 had extrapulmonary metastases [17]. Another study of 98 bone lesions in a general oncologic population undergoing simultaneous FDG-PET/CT and FDG-PET/MRI showed these modalities to be equivalent for the detection and characterization of bone lesions [38]. Although FDG-PET/MRI whole body scans may prove to be useful in this setting, additional evidence is needed to compare its utility with existing modalities.

Fluoride PET/CT Whole Body
Fluoride PET/CT can increase diagnostic confidence when detecting bone metastases in general oncologic populations when compared with planar Tc-99m bone scans [39]. There is no relevant literature to specifically

support the use of fluoride PET/CT in the initial staging for extrapulmonary metastasis of malignant or aggressive musculoskeletal tumors. Specifically, extraosseous extrapulmonary metastases will usually be occult on fluoride PET/CT whole body scans.

MRI Whole Body Without and With IV Contrast
There is no relevant literature to support the use of MRI whole body without and with IV contrast in the initial staging for extrapulmonary metastasis of malignant or aggressive musculoskeletal tumors. However, the addition of IV contrast can be helpful for assessing soft tissue masses and therefore could be beneficial in this setting.

MRI Whole Body Without IV Contrast
The ability of MRI to characterize soft tissue and bone marrow make it ideal for identifying extrapulmonary metastases. MRI is particularly useful in identifying and accurately characterizing bone marrow abnormalities as metastases versus nonmalignant processes. Hematopoietic marrow, or red marrow, is a frequently encountered nonmalignant marrow abnormality that can be mistaken for a metastasis on other modalities, particularly on PET imaging, when there is relatively increased metabolic activity. Hematopoietic marrow is abundant in the pediatric and young adult populations making it problematic for the staging of bone sarcomas in these populations. Multiple medications and other systemic illnesses can activate hematopoietic marrow in the adult population.

Specific to myxoid liposarcoma, a sarcoma subtype known to metastasize preferentially to extrapulmonary locations, multiple studies have found MRI to be more accurate than FDG-PET, FDG-PET/CT, CT, radiography, and bone scintigraphy imaging to detect extrapulmonary metastases [40-44].

A small study in patients with Ewing sarcoma showed more bone lesions were more accurately identified on MRI whole body when compared with FDG-PET/CT [35]. There are mixed conclusions when comparing FDG-PET/CT versus MRI whole body in detecting osseous metastases in general oncology populations [32-34].

MRI whole body is more sensitive than Tc-99m bone scan for detecting osseous metastasis in a variety of tumors known to metastasize to bone. Sensitivity was also higher specifically in patients with Ewing sarcoma [29].

Radiography Area of Interest
Radiographs could be used to evaluate an area of interest identified clinically or from another imaging modality. There is no relevant literature to support the use of radiography at an area of interest in the initial staging for extrapulmonary metastasis of malignant or aggressive musculoskeletal tumors.

US Area of Interest
There is no relevant literature to support the use of ultrasound (US) area of interest in the initial staging for extrapulmonary metastasis of malignant or aggressive musculoskeletal tumors. US could be used to evaluate an area of interest identified clinically or from another imaging modality. US is more useful to evaluate superficial soft tissue masses as opposed to bone lesions, which are usually occult if there is no cortical breakthrough.

Variant 3: Malignant or aggressive primary musculoskeletal tumor with no suspected or known recurrence. Surveillance for pulmonary metastasis.

Pulmonary metastases account for the majority of distant metastatic disease in patients with primary extremity sarcoma as a whole. Risk of pulmonary metastasis varies with tumor histology and grade. Although patients with high-grade soft tissue sarcomas develop lung metastasis at a rate of ~60%, those with low-grade sarcomas have lung metastasis rates <10% [45,46]. Therefore, guidance regarding modality for lung screening often differ between low-risk and high-risk patients. There is also debate concerning the frequency of lung surveillance. Given most pulmonary metastases will occur within 2 years of primary resection [47], many experts support more frequent surveillance initially in the first few years after diagnosis. Surveillance regimens usually de-escalate to annual follow-up after 5 years postresection [48-52]. Although these dynamic protocols are often used, a prospective randomized trial of 500 patients with resected extremity sarcomas and no baseline metastatic disease found no difference in overall survival or recurrence-free survival between groups whether surveilled at 3 month or 6-month consistent intervals [53,54]. Pulmonary metastases are associated with a worse prognosis [45], and treatment of these pulmonary metastases can improve survival [8,10]. Identification of pulmonary metastases is an essential part of primary musculoskeletal tumor screening. There is little to no variation in the ability of a certain modality to detect pulmonary metastasis whether performed at initial staging (see Variant 1), surveillance, or restaging in the setting of recurrence.

CT Chest With IV Contrast
There is no relevant literature regarding the specific use of CT chest with IV contrast in the evaluation of pulmonary metastasis from malignant or aggressive primary musculoskeletal tumors. However, IV contrast may lead to equivocal assessment of mineralization, which can be a useful morphologic feature to distinguish benign versus malignant pulmonary nodules. Therefore, CT chest with IV contrast is not generally useful as the sole imaging technique, and there is felt to be little additional benefit in the CT assessment of pulmonary nodules without and with IV contrast compared to CT chest without IV contrast in this setting.

CT Chest Without and With IV Contrast
There is no relevant literature regarding the specific use of CT chest without and with IV contrast in the evaluation of pulmonary metastasis from malignant or aggressive primary musculoskeletal tumors. However, IV contrast may lead to equivocal assessment of mineralization which can be a useful morphologic feature to distinguish benign versus malignant pulmonary nodules. Therefore, CT chest with IV contrast is not generally useful as the sole imaging technique, and there is felt to be little additional benefit in the CT assessment of pulmonary nodules without and with IV contrast compared to CT chest without IV contrast in this setting.

CT Chest Without IV Contrast
CT chest is the most sensitive imaging modality for the detection of pulmonary metastases. CT imaging for lung metastases has been criticized by some as being too sensitive. Several studies have attempted to find size and morphologic criteria to help discriminate between malignant and benign pulmonary nodules [9,12]. Rissing et al [55] showed that those only with pulmonary lesions <5 mm were associated with equivalent survival to those with normal scans. Often when a pulmonary metastasis is identified on a different imaging modality, CT is then required for biopsy or treatment planning.

Guidance varies regarding whether to use CT chest versus chest radiography as surveillance for lung metastases in patients with sarcoma. Much of the debate also takes cost-analysis and radiation exposure into consideration. A retrospective study by Cho et al [56] of 176 patients with stage II or stage III high-grade extremity sarcomas calculated similar 5-year survival rates whether surveilled with chest radiography or CT chest. However, when stratifying survival rates by stage, they found a survival benefit for stage III patients when monitored with CT chest likely related to the increased rates of lung metastasis with high-grade sarcoma. Other studies have differing conclusions. A large multicenter retrospective study by Gamboa et al [45] comparing lung surveillance in 909 patients with extremity, truncal, or retroperitoneal high-grade soft tissue sarcomas found the 5-year survival rate was noninferior for patients followed with chest radiography versus CT chest (71% versus 60%). This study also found there was no difference in the rate or type of intervention for these lung metastases when detected. Selection bias was a limitation of both of these retrospective studies because the rationale of which modality used to screen was not known or reported. Additionally, the Gamboa et al [45] study included 151 patients with retroperitoneal sarcoma, which has a high rate of local recurrence; this group was overrepresented in the CT imaging group, which had the worse survival rate. A prospective randomized trial of 500 patients with resected extremity bone and soft tissue sarcomas without baseline metastases showed noninferiority of chest radiography compared with CT chest with similar overall survival (56% versus 53% respectively) and recurrence-free survival (59% versus 54% respectively) when used for lung surveillance [53,54].

FDG-PET/CT Whole Body
Although FDG-PET/CT is not as sensitive for detecting pulmonary metastases as CT chest imaging, it has been shown to be more specific and therefore may be useful as a problem-solving tool when an indeterminate pulmonary nodule is detected on diagnostic chest CT. A study comparing staging and follow-up imaging studies in 41 children with primary bone sarcomas showed greater sensitivity of CT chest (93%) versus FDG-PET/CT (80%) in detecting pulmonary metastases (although specificity was higher with FDG-PET/CT at 96% compared with 87% for CT chest). Of the false-negative FDG-PET/CT results in that study, half were pulmonary nodules <10 mm [15]. Evaluation of subcentimeter pulmonary nodules is a known limitation of FDG-PET/CT because of the inherent resolution constraints of PET/CT technology and respiratory motion artifact. However, a study of 63 lung nodules in 18 pediatric patients with bone sarcoma did demonstrate the benefit of using an FDG-PET SUV cutoff in evaluating small pulmonary nodules; using an SUV_{max} >1 cutoff value and a nodule diameter cutoff of 6 mm can differentiate benign and malignant nodules with an accuracy of 92.1% compared with an accuracy of 88.9% with FDG-PET/CT visual analysis alone [16].

FDG-PET/MRI Whole Body
There is no relevant literature to support the use of FDG-PET/MRI in the evaluation of pulmonary metastases during surveillance of malignant or aggressive primary musculoskeletal tumors. The inherent decreased spatial resolution of MRI compared with CT raises doubts about the ability to identify small pulmonary metastases with FDG-PET/MRI as accurately as CT. MRI of the lungs relies heavily on the ability to minimize respiratory motion.

Radiography Chest
Chest radiography is less sensitive than CT chest imaging for the detection of pulmonary nodules. Whooley et al [57] found that 83% of asymptomatic metastases were detected radiographically with a positive predictive value of 92% and a negative predictive value of 97%. However, the detection of more and smaller pulmonary metastases with CT versus radiography has definitely not improved survival rates. Although radiography is less sensitive for detection of lung metastases, how that correlates with clinically significant metastases is less certain.

Variant 4: Malignant or aggressive primary bone tumor. Surveillance for local recurrence.

The body regions covered in this clinical scenario are ankle, chest, elbow, shoulder, femur, foot, forearm, hand, humerus, knee, pelvis, tibia/fibula, and wrist.

Local recurrence rates following primary resection of a malignant or aggressive bone tumor vary and depend on tumor grade and histology. Local recurrence rates of bone sarcomas are reported to be approximately 10% to 15% in patients with osteosarcoma and Ewing sarcoma [58-61]. Prognosis is poor for locally recurrent malignant or aggressive bone tumors, with postrecurrence 5-year survival rates reported approximately 15% to 30% in patients with osteosarcoma and 5% in patients with Ewing sarcoma [60,62]. Factors associated with poorer prognosis in patients with osteosarcoma were size of local recurrence (>5 cm) and presence of distant metastasis [60].

Recommendations for local recurrence surveillance imaging vary amongst expert guidelines, although all acknowledge the benefit of clinical evaluation. Locally recurrent bone tumors can often present as a soft tissue mass, and in a study of osteosarcoma local recurrences, the majority (approximately 75%) were soft tissue masses rather than bone lesions [60]. Some guidelines recommend clinical examination to be performed solely, whereas others recommend in combination with imaging [49,51,52,63]. Time to recurrence also varies with tumor histology. Most osteosarcoma local recurrences have been shown to occur within 5 years of resection. However, late recurrence of both osteosarcoma and Ewing sarcoma have been reported [60,61]. In a study of locally recurrent osteosarcoma, survival rates decreased from 30% at 5 years to 13% at 10 years, suggesting long-term follow-up beyond 5 years is beneficial. Tumor histology, grade, and clinical scenario remain paramount when deciding how to surveil for local recurrence.

Bone Scan Whole Body
Historically, bone scans have been used for the surveillance of local recurrence. Increased bone uptake at the primary resection site is nonspecific and can occur for many reasons, including stress changes from adjacent hardware, fractures, and possibly recurrence. With advances in MRI, CT, and PET imaging, the use of bone scan for local recurrence surveillance has decreased. Studies have shown superiority of FDG-PET/CT and MRI versus bone scan for assessment of bone metastases (see Variant 2). Although historically, Tc-99m bone scan has been used to detect bone metastasis, more recent studies have shown Tc-99m bone scan is inferior to FDG-PET/CT in the detection of bone metastases in general oncologic populations [23]. A smaller study of 64 pediatric patients with bone sarcoma also showed greater accuracy of FDG-PET/CT (84%) versus Tc-99m bone scan (70%) in detecting bone metastases during initial staging [22]. There is no relevant literature to support the use of bone scan whole body for surveillance of local recurrence of malignant or aggressive primary bone tumors.

Bone Scan Whole Body with SPECT or SPECT/CT Area of Interest
There is no relevant literature to support the use of bone scan whole body with SPECT or SPECT/CT area of interest for surveillance of local recurrence of malignant or aggressive primary bone tumors.

CT Area of Interest With IV Contrast
CT can be useful for surveillance of local recurrence when MRI is unable to be obtained. CT imaging can also be of benefit if metal artifact on MRI cannot be resolved, although it should be noted, CT is also susceptible to artifact from metal hardware. Although IV contrast does not provide added benefit for evaluation of bone, given many bone sarcoma recurrences present as soft tissue masses, IV contrast can be useful to increase the conspicuity of enhancing soft tissue tumors.

CT Area of Interest Without and With IV Contrast
CT can be useful for surveillance of local recurrence when MRI is unable to be obtained. CT imaging can also be of benefit if metal artifact on MRI cannot be resolved, although it should be noted, CT is also susceptible to artifact from metal hardware. Although IV contrast does not provide added benefit for evaluation of bone, given many bone sarcoma recurrences present as soft tissue masses, IV contrast can be useful to increase the conspicuity of enhancing soft tissue tumors. However, given increased radiation dose without clinical benefit, CT without and with IV contrast is usually not recommended over CT with IV contrast alone.

CT Area of Interest Without IV Contrast
CT can be useful for surveillance of local recurrence when MRI is unable to be obtained. CT imaging can also be of benefit if metal artifact on MRI cannot be resolved, although it should be noted, CT is also susceptible to artifact from metal hardware. Although IV contrast does not provide added benefit for evaluation of bone, given many bone sarcoma recurrences present as soft tissue masses, IV contrast can be useful to increase the conspicuity of enhancing soft tissue tumors and is usually recommended in this setting.

FDG-PET/CT Whole Body
FDG-PET/CT has the added benefit of not only thin-slice CT imaging but also the ability to detect metabolically active disease. FDG-PET/CT is highly accurate in detecting recurrent soft tissue and bone sarcomas, and may be useful as a problem-solving tool when other imaging of the area of interest is equivocal. In a retrospective single-institution study of 53 patients with skeletal Ewing sarcoma, FDG-PET/CT was found to have a sensitivity of 95% and a specificity of 87% in detecting recurrence as a whole with local recurrence accounting for 90% of those recurrences. Accuracy further increased when there was clinical suspicion of local recurrence (84% increased to 94%) [64]. The degree of metabolic activity as quantified by SUV_{max} has also shown utility for predicting prognosis, with 1 study of patients with chondrosarcoma identifying a SUV_{max} cutoff of 6.15 to predict significant differences in survival ($P < .001$) [65]. A study of postoperative patients with extremity osteosarcoma with endoprosthetic reconstruction reported that an SUV_{max} >4.6 plus ΔSUV >75% after surgery can reliably distinguish recurrence from posttreatment activity that can linger for 3 years following resection [66].

FDG-PET/MRI Whole Body
There is no relevant literature to support the use of FDG-PET/MRI whole body as surveillance of local recurrence of malignant or aggressive primary bone tumors.

Fluoride PET/CT Whole Body
There is no relevant literature to support the use of fluoride PET/CT whole body as surveillance of local recurrence of malignant or aggressive primary bone tumors.

MRI Area of Interest Without and With IV Contrast
MRI of the primary tumor resection site has further asserted its usefulness for surveillance of local recurrence with improvements in metal artifact reduction. Given the preference for limb-sparing surgeries, many bone tumor resections require the implantation of hardware which creates local artifact that can obscure the adjacent tissues. Few studies comparing the use of MRI for local recurrence of bone tumors compared with other modalities have been published in recent years likely given its widespread adoption clinically. MRI is often requested before surgery and radiation when local recurrence is established.

Given many local recurrences are soft tissue masses, the use of IV contrast remains beneficial to help characterize masses as malignant or benign and can also increase reader confidence [67,68].

MRI Area of Interest Without IV Contrast
MRI of the primary tumor resection site has further asserted its usefulness for surveillance of local recurrence with improvements in metal artifact reduction. Given the preference for limb-sparing surgeries, many bone tumor resections require the implantation of hardware, which creates local artifact that can obscure the adjacent tissues. Few studies comparing the use of MRI for local recurrence of bone tumors compared with other modalities have been published in recent years likely given its widespread adoption clinically. MRI is often requested before surgery and radiation when local recurrence is established.

Given many local recurrences are soft tissue masses, the use of IV contrast remains beneficial to help characterize masses as malignant or benign and can also increase reader confidence. However, the inherent contrast resolution of MRI, even in the absence of IV contrast, makes this a useful modality to assess for local recurrence of malignant or aggressive primary bone tumors [67,68].

Radiography Area of Interest
Not only is radiography useful to evaluate for bone tumor recurrence, but it is also an invaluable adjunct to MRI interpretation. When hardware is present, even with modern metal-artifact reduction techniques, radiography can visualize the bone-metal or bone-cement interface, which can be critical to evaluate for tumor recurrence. Radiographs are recommended for the surveillance of local recurrence of malignant or aggressive primary bone tumors.

US Area of Interest
US is not useful for evaluating bone lesions when there is no extraosseous tumor extension. However, US may be beneficial if a mass is identified clinically. There is no relevant literature to support the use of US as surveillance for asymptomatic local recurrence of malignant or aggressive primary bone tumors.

Variant 5: Malignant or aggressive primary soft tissue tumor. Surveillance for local recurrence.

The body regions covered in this clinical scenario are abdomen, ankle, chest, elbow, shoulder, thigh, foot, forearm, hand, arm, knee, pelvis, leg, and wrist.

Local recurrence rates of soft tissue sarcomas have been reported to occur at rates of 5% to 25% in larger historic studies [69-72]. Although rates of local recurrence following primary resection depend on tumor histology and grade, several other factors have been identified that increase risk. Tumor location is associated with local recurrence, with those tumors located deep to fascia or in the upper extremities/trunk as more likely to recur [73]. Positive or close resection margins have also been associated with increased likelihood of local recurrence [70,73,74]. Local recurrence is associated with metastatic disease and increased mortality [70], and if the recurrence can be treated before developing metastatic disease there is a survival benefit [73]. Size of the recurrence has also been linked with not only survival [75] but also morbidity, because larger tumors often require more extensive surgery [48]. Therefore, surveillance for local recurrence is important to reduce both mortality and morbidity.

There remains some controversy not only on how to surveil resected soft tissue sarcomas but also if imaging surveillance is even necessary. The primary dispute against the need for imaging surveillance is the argument that recurrences are usually clinically detectable [54,76]. The literature also has some conflicting evidence on this topic. For example, a prospective study of 500 patients with sarcoma found 90% of local recurrences were clinically detected [54]. Conversely, a large recent study of 325 patients with soft tissue sarcomas found a rate of 60% of the local recurrences were not detected clinically [77]. Expert guidelines vary on recommendations for local recurrence imaging, although all acknowledge the benefit of clinical evaluation; some guidelines recommend clinical examination to be performed solely, whereas others recommend in combination with imaging [49,51,52,63]. Clinical evaluation of deep soft tissue local recurrence remains a limitation of this approach. Most local recurrences of soft tissue sarcomas occur within 5 years of primary resection [78]. Therefore, those guidelines that recommend imaging usually advocate for more aggressive imaging in the first 5 years that taper off to annual imaging. Tumor histology, grade, and clinical scenario remain paramount when deciding how to surveil for local recurrence.

CT Area of Interest With IV Contrast
CT remains useful for surveillance of local recurrence when MRI is unable to be obtained. CT imaging can also be of benefit if metal artifact on MRI cannot be resolved, although it should be noted CT is also susceptible to artifact from metal hardware. When evaluating the soft tissues, postcontrast imaging is recommended to increase the conspicuity of enhancing tumors and, if so, areas of necrosis that can help with biopsy planning and to serve as a baseline for future therapy response assessment.

CT Area of Interest Without and With IV Contrast
CT remains useful for surveillance of local recurrence when MRI is unable to be obtained. CT imaging can also be of benefit if metal artifact on MRI cannot be resolved, although it should be noted CT is also susceptible to artifact from metal hardware. When evaluating the soft tissues, postcontrast imaging is recommended to increase the conspicuity of enhancing tumors and, if so, areas of necrosis that can help with biopsy planning and to serve as a baseline for future therapy response assessment. However, CT without and with IV contrast is usually not recommended over CT with IV contrast alone.

CT Area of Interest Without IV Contrast
CT remains useful for surveillance of local recurrence when MRI is unable to be obtained. CT imaging can also be of benefit if metal artifact on MRI cannot be resolved, although it should be noted CT is also susceptible to artifact from metal hardware. When evaluating the soft tissues, postcontrast imaging is recommended to increase the

conspicuity of enhancing tumors and, if so, areas of necrosis that can help with biopsy planning and to serve as a baseline for future therapy response assessment.

FDG-PET/CT Whole Body

FDG-PET/CT has the added benefit of not only thin-slice CT imaging but also the ability to detect metabolically active disease. FDG-PET/CT is highly accurate in detecting recurrent soft tissue and bone sarcomas, and may be useful as a problem-solving tool when other imaging of the area of interest is equivocal. A retrospective single-institution study of 43 patients with bone or soft tissue sarcomas found better sensitivity and specificity of FDG-PET/CT follow-up versus contrast-enhanced CT imaging (94% and 92% versus 78% and 67%, respectively) [79]. A retrospective single-institution study of 152 patients with soft tissue sarcomas comparing whole body FDG-PET/CT with MRI at the primary treatment site did not detect a significant difference in performance for detecting local recurrence (MRI sensitivity of 90% and specificity of 98%, compared with FDG-PET/CT sensitivity of 95% and specificity of 96%) [80].

FDG-PET/MRI Whole Body

A retrospective single-institution study of 41 patients with resected soft tissue sarcomas and with clinically suspicious recurrence underwent FDG-PET/MRI, either whole body if a truncal primary or localized to the primary tumor site if an extremity sarcoma. The MRI portion and then FDG-PET/MRI portions were interpreted independently. With the addition of FDG-PET imaging to the MRI, sensitivity increased from 82% to 96%, although specificity mildly decreased from 85% to 79%. Diagnostic confidence increased for the readers [81]. FDG-PET/MRI whole body may be useful as a problem-solving tool when other imaging of the area of interest is equivocal.

MRI Area of Interest Without and With IV Contrast

MRI used as surveillance of the primary soft tissue tumor site is the mainstay for evaluating local recurrence. Few studies regarding the diagnostic utility of MRI for local recurrence of soft tissue sarcomas have been published in recent years, likely given its widespread adoption clinically. MRI is useful not only for asymptomatic surveillance but also if a clinical area of concern at the resection site develops. MRI is often requested before surgery and radiation when local recurrence is established. A retrospective single-institution study by Park et al [77] of 325 patients with extremity sarcoma with a local recurrence rate of 11% found MRI detected 60% of those patients with recurrence not identified clinically or with US. Those with MRI detected local recurrence trended towards better survival, but this did not reach statistical significance.

MRI has been criticized as having many false-positive results, leading to unnecessary procedures and emotional distress [82]. A retrospective single-institution study of 11 local recurrences in 124 patients with soft tissue sarcoma found MRI had a positive predictive value of only 42% with 11 false-positive examinations in this cohort and advocated for clinical surveillance only [83]. However, the Park et al [77] larger single-institution studies found a positive predictive value of 93%.

Postcontrast imaging has been shown to add benefit in evaluation of soft tissue tumors to differentiate benign versus malignant lesions [68]. A more recent retrospective study assessing the added value of postcontrast MRI showed contrast improved reader confidence even for experienced readers and improved accuracy of a more inexperienced reader from 65% to 72% [67].

MRI Area of Interest Without IV Contrast

MRI used as surveillance of the primary soft tissue tumor site is the mainstay for evaluating local recurrence. Few studies regarding the diagnostic utility of MRI for local recurrence of soft tissue sarcomas have been published in recent years, likely given its widespread adoption clinically. MRI is useful not only for asymptomatic surveillance but also if a clinical area of concern at the resection site develops. MRI is often requested before surgery and radiation when local recurrence is established. A retrospective single-institution study by Park et al [77] of 325 patients with extremity sarcoma with a local recurrence rate of 11% found MRI detected 60% of those patients with recurrence not identified clinically or with US. Those with MRI detected local recurrence trended towards better survival but this did not reach statistical significance.

MRI has been criticized as having many false-positive results leading to unnecessary procedures and emotional distress [82]. A retrospective single-institution study of 11 local recurrences in 124 patients with soft tissue sarcoma found MRI had a positive predictive value of only 42% with 11 false-positive examinations in this cohort and advocated for clinical surveillance only [83]. However, the Park et al [77] larger single-institution studies found a positive predictive value of 93%.

Postcontrast imaging has been shown to add benefit in evaluation of soft tissue tumors to differentiate benign versus malignant lesions [68]. A more recent retrospective study assessing the added value of postcontrast MRI showed contrast improved reader confidence even for experienced readers and improved accuracy of a more inexperienced reader from 65% to 72% [67]. However, MRI without IV contrast is still highly sensitive in detecting local recurrence of soft tissue tumor because of an inherent soft tissue contrast of MRI and therefore is still of benefit.

Radiography Area of Interest

In rare instances of a primary soft tissue tumor that produces osseous or chondroid matrix, there may be limited benefit of radiography area of interest for detecting local recurrence, but in general this modality is usually not helpful for most patients. There is no relevant literature to support the use of radiography alone as surveillance for local recurrence of malignant or aggressive primary soft tissue tumors.

US Area of Interest

Local recurrence of a soft tissue tumor can be detected with US. Note that most studies comparing US with MRI are outdated because both US and MRI technology have advanced significantly. A more recent retrospective single-center study of 68 patients with extremity soft tissue sarcomas (28% recurrence rate) followed with US and MRI found a sensitivity of 88% and specificity of 94% in the detection of local recurrences with US, with a negative predictive value of 96%; both US false-negative lesions were identified with MRI in this study [84].

Summary of Recommendations

- **Variant 1**: CT chest without IV contrast is usually appropriate for the initial staging of malignant or aggressive primary musculoskeletal tumors in the evaluation of pulmonary metastases.
- **Variant 2**: FDG-PET/CT whole body is usually appropriate for the initial staging of malignant or aggressive primary musculoskeletal tumors in the evaluation of extrapulmonary metastases. Although the panel did not agree on recommending MRI whole body without IV contrast or fluoride PET/CT whole body, because there is insufficient medical literature to conclude whether these patients would benefit from the procedure, its use may be appropriate.
- **Variant 3**: CT chest without IV contrast is usually appropriate for surveillance of pulmonary metastasis in patients with malignant or aggressive primary musculoskeletal tumors with no suspected or known recurrence.
- **Variant 4**: Radiography area of interest, combined with MRI area of interest without and with IV contrast or MRI area of interest without IV contrast are usually appropriate for surveillance of local recurrence in patients with malignant or aggressive primary bone tumors. These procedures are complementary, and both are indicated in this patient population.
- **Variant 5**: MRI area of interest without and with IV contrast or MRI area of interest without IV contrast is usually appropriate for surveillance of local recurrence in patients with malignant or aggressive primary soft tissue tumors. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care). Although the panel did not agree on recommending US area of interest as there are limited data comparing its utility relative to other established imaging modalities such as MRI, its use 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 [85].

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."		

References

1. *WHO Classification of Tumours Editorial Board. Soft tissue and bone tumours.* 5th ed. Lyon (France): IARC Press; 2020.

2. National Cancer Institute. Surveillance, Epidemiology, and End Results Program. Cancer Stat Facts: Soft Tissue including Heart Cancer. Available at: https://seer.cancer.gov/statfacts/html/soft.html. Accessed March 31, 2022.
3. National Cancer Institute. Surveillance, Epidemiology, and End Results Program. Cancer Stat Facts: Bone and Joint Cancer. Available at: https://seer.cancer.gov/statfacts/html/bones.html. Accessed March 31, 2022.
4. Becher S, Oskouei S. PET Imaging in Sarcoma. Orthop Clin North Am 2015;46:409-15, xi.
5. Billingsley KG, Lewis JJ, Leung DH, Casper ES, Woodruff JM, Brennan MF. Multifactorial analysis of the survival of patients with distant metastasis arising from primary extremity sarcoma. Cancer 1999;85:389-95.
6. Liu F, Zhang Q, Zhou D, Dong J. Effectiveness of (18)F-FDG PET/CT in the diagnosis and staging of osteosarcoma: a meta-analysis of 26 studies. BMC Cancer 2019;19:323.
7. Mirabello L, Troisi RJ, Savage SA. Osteosarcoma incidence and survival rates from 1973 to 2004: data from the Surveillance, Epidemiology, and End Results Program. Cancer 2009;115:1531-43.
8. Briccoli A, Rocca M, Salone M, Guzzardella GA, Balladelli A, Bacci G. High grade osteosarcoma of the extremities metastatic to the lung: long-term results in 323 patients treated combining surgery and chemotherapy, 1985-2005. Surg Oncol 2010;19:193-9.
9. Ciccarese F, Bazzocchi A, Ciminari R, et al. The many faces of pulmonary metastases of osteosarcoma: Retrospective study on 283 lesions submitted to surgery. Eur J Radiol 2015;84:2679-85.
10. Diemel KD, Klippe HJ, Branseheid D. Pulmonary metastasetomy for osteosarcoma: is it justified? Recent Results Cancer Res 2009;179:183-208.
11. Kayton ML, Huvos AG, Casher J, et al. Computed tomographic scan of the chest underestimates the number of metastatic lesions in osteosarcoma. J Pediatr Surg 2006;41:200-6; discussion 00-6.
12. Dudeck O, Zeile M, Andreou D, et al. Computed tomographic criteria for the discrimination of subcentimeter lung nodules in patients with soft-tissue sarcomas. Clin Imaging 2011;35:174-9.
13. Piperkova E, Mikhaeil M, Mousavi A, et al. Impact of PET and CT in PET/CT studies for staging and evaluating treatment response in bone and soft tissue sarcomas. Clin Nucl Med 2009;34:146-50.
14. Roberge D, Vakilian S, Alabed YZ, Turcotte RE, Freeman CR, Hickeson M. FDG PET/CT in Initial Staging of Adult Soft-Tissue Sarcoma. Sarcoma 2012;2012:960194.
15. London K, Stege C, Cross S, et al. 18F-FDG PET/CT compared to conventional imaging modalities in pediatric primary bone tumors. Pediatr Radiol 2012;42:418-30.
16. Cistaro A, Lopci E, Gastaldo L, Fania P, Brach Del Prever A, Fagioli F. The role of 18F-FDG PET/CT in the metabolic characterization of lung nodules in pediatric patients with bone sarcoma. Pediatr Blood Cancer 2012;59:1206-10.
17. Platzek I, Beuthien-Baumann B, Schramm G, et al. FDG PET/MR in initial staging of sarcoma: Initial experience and comparison with conventional imaging. Clin Imaging 2017;42:126-32.
18. Fuglo HM, Maretty-Nielsen K, Hovgaard D, Keller JO, Safwat AA, Petersen MM. Metastatic pattern, local relapse, and survival of patients with myxoid liposarcoma: a retrospective study of 45 patients. Sarcoma 2013;2013:548628.
19. Jha P, Frolich AM, McCarville B, et al. Unusual association of alveolar rhabdomyosarcoma with pancreatic metastasis: emerging role of PET-CT in tumor staging. Pediatr Radiol 2010;40:1380-6.
20. Nishida Y, Tsukushi S, Urakawa H, et al. High incidence of regional and in-transit lymph node metastasis in patients with alveolar rhabdomyosarcoma. Int J Clin Oncol 2014;19:536-43.
21. Cotterill SJ, Ahrens S, Paulussen M, et al. Prognostic factors in Ewing's tumor of bone: analysis of 975 patients from the European Intergroup Cooperative Ewing's Sarcoma Study Group. J Clin Oncol 2000;18:3108-14.
22. Quartuccio N, Fox J, Kuk D, et al. Pediatric bone sarcoma: diagnostic performance of (1)(8)F-FDG PET/CT versus conventional imaging for initial staging and follow-up. AJR 2015;204:153-60.
23. Chang CY, Gill CM, Joseph Simeone F, et al. Comparison of the diagnostic accuracy of 99 m-Tc-MDP bone scintigraphy and 18 F-FDG PET/CT for the detection of skeletal metastases. Acta Radiol 2016;57:58-65.
24. Byun BH, Kong CB, Lim I, et al. Comparison of (18)F-FDG PET/CT and (99 m)Tc-MDP bone scintigraphy for detection of bone metastasis in osteosarcoma. Skeletal Radiol 2013;42:1673-81.
25. Cook GJ, Houston S, Rubens R, Maisey MN, Fogelman I. Detection of bone metastases in breast cancer by 18FDG PET: differing metabolic activity in osteoblastic and osteolytic lesions. J Clin Oncol 1998;16:3375-9.
26. Gallowitsch HJ, Kresnik E, Gasser J, et al. F-18 fluorodeoxyglucose positron-emission tomography in the diagnosis of tumor recurrence and metastases in the follow-up of patients with breast carcinoma: a comparison to conventional imaging. Invest Radiol 2003;38:250-6.

27. Huyge V, Garcia C, Vanderstappen A, Alexiou J, Gil T, Flamen P. Progressive osteoblastic bone metastases in breast cancer negative on FDG-PET. Clin Nucl Med 2009;34:417-20.
28. Ozulker T, Kucukoz Uzun A, Ozulker F, Ozpacac T. Comparison of (18)F-FDG-PET/CT with (99m)Tc-MDP bone scintigraphy for the detection of bone metastases in cancer patients. Nucl Med Commun 2010;31:597-603.
29. Kalus S, Saifuddin A. Whole-body MRI vs bone scintigraphy in the staging of Ewing sarcoma of bone: a 12-year single-institution review. Eur Radiol 2019;29:5700-08.
30. Adusumilli P, Nejadhamzeeigilani H, Pitts K, et al. Protocol-driven multidetector SPECT/CT: integration of hybrid imaging into the routine workflow of whole-body bone scintigraphy in oncology patients. Clin Radiol 2020;75:79 e1-79 e7.
31. Webb HR, Latifi HR, Griffeth LK. Utility of whole-body (head-to-toe) PET/CT in the evaluation of melanoma and sarcoma patients. Nucl Med Commun 2018;39:68-73.
32. Antoch G, Vogt FM, Freudenberg LS, et al. Whole-body dual-modality PET/CT and whole-body MRI for tumor staging in oncology. JAMA 2003;290:3199-206.
33. Daldrup-Link HE, Franzius C, Link TM, et al. Whole-body MR imaging for detection of bone metastases in children and young adults: comparison with skeletal scintigraphy and FDG PET. AJR 2001;177:229-36.
34. Schmidt GP, Schoenberg SO, Schmid R, et al. Screening for bone metastases: whole-body MRI using a 32-channel system versus dual-modality PET-CT. Eur Radiol 2007;17:939-49.
35. Bosma SE, Vriens D, Gelderblom H, van de Sande MAJ, Dijkstra PDS, Bloem JL. (18)F-FDG PET-CT versus MRI for detection of skeletal metastasis in Ewing sarcoma. Skeletal Radiol 2019;48:1735-46.
36. Ricard F, Cimarelli S, Deshayes E, Mognetti T, Thiesse P, Giammarile F. Additional Benefit of F-18 FDG PET/CT in the staging and follow-up of pediatric rhabdomyosarcoma. Clin Nucl Med 2011;36:672-7.
37. Volker T, Denecke T, Steffen I, et al. Positron emission tomography for staging of pediatric sarcoma patients: results of a prospective multicenter trial. J Clin Oncol 2007;25:5435-41.
38. Eiber M, Takei T, Souvatzoglou M, et al. Performance of whole-body integrated 18F-FDG PET/MR in comparison to PET/CT for evaluation of malignant bone lesions. J Nucl Med 2014;55:191-7.
39. Lofgren J, Mortensen J, Rasmussen SH, et al. A Prospective Study Comparing (99m)Tc-Hydroxyethylene-Diphosphonate Planar Bone Scintigraphy and Whole-Body SPECT/CT with (18)F-Fluoride PET/CT and (18)F-Fluoride PET/MRI for Diagnosing Bone Metastases. J Nucl Med 2017;58:1778-85.
40. Durr HR, Rauh J, Baur-Melnyk A, et al. Myxoid liposarcoma: local relapse and metastatic pattern in 43 patients. BMC Cancer 2018;18:304.
41. Gorelik N, Reddy SMV, Turcotte RE, et al. Early detection of metastases using whole-body MRI for initial staging and routine follow-up of myxoid liposarcoma. Skeletal Radiol 2018;47:369-79.
42. Gouin F, Renault A, Bertrand-Vasseur A, et al. Early detection of multiple bone and extra-skeletal metastases by body magnetic resonance imaging (BMRI) after treatment of Myxoid/Round-Cell Liposarcoma (MRCLS). Eur J Surg Oncol 2019;45:2431-36.
43. Noble JL, Moskovic E, Fisher C, Judson I. Imaging of skeletal metastases in myxoid liposarcoma. Sarcoma 2010;2010:262361.
44. Stevenson JD, Watson JJ, Cool P, et al. Whole-body magnetic resonance imaging in myxoid liposarcoma: A useful adjunct for the detection of extra-pulmonary metastatic disease. Eur J Surg Oncol 2016;42:574-80.
45. Gamboa AC, Ethun CG, Switchenko JM, et al. Lung Surveillance Strategy for High-Grade Soft Tissue Sarcomas: Chest X-Ray or CT Scan? J Am Coll Surg 2019;229:449-57.
46. Miller BJ, Carmody Soni EE, Reith JD, Gibbs CP, Scarborough MT. CT scans for pulmonary surveillance may be overused in lower-grade sarcoma. Iowa Orthop J 2012;32:28-34.
47. Rehders A, Hosch SB, Scheunemann P, Stoecklein NH, Knoefel WT, Peiper M. Benefit of surgical treatment of lung metastasis in soft tissue sarcoma. Arch Surg 2007;142:70-5; discission 76.
48. Cipriano CA, Jang E, Tyler W. Sarcoma Surveillance: A Review of Current Evidence and Guidelines. J Am Acad Orthop Surg 2020;28:145-56.
49. Dangoor A, Seddon B, Gerrand C, Grimer R, Whelan J, Judson I. UK guidelines for the management of soft tissue sarcomas. Clin Sarcoma Res 2016;6:20.
50. Gerrand C, Athanasou N, Brennan B, et al. UK guidelines for the management of bone sarcomas. Clin Sarcoma Res 2016;6:7.
51. ESMO/European Sarcoma Network Working Group. Soft tissue and visceral sarcomas: ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up. Ann Oncol 2014;25 Suppl 3:iii102-12.

52. von Mehren M, Randall RL, Benjamin RS, et al. Soft Tissue Sarcoma, Version 2.2018, NCCN Clinical Practice Guidelines in Oncology. J Natl Compr Canc Netw 2018;16:536-63.
53. Puri A, Ranganathan P, Gulia A, Crasto S, Hawaldar R, Badwe RA. Does a less intensive surveillance protocol affect the survival of patients after treatment of a sarcoma of the limb? updated results of the randomized TOSS study. Bone Joint J 2018;100-B:262-68.
54. Puri A, Gulia A, Hawaldar R, Ranganathan P, Badwe RA. Does intensity of surveillance affect survival after surgery for sarcomas? Results of a randomized noninferiority trial. Clin Orthop Relat Res 2014;472:1568-75.
55. Rissing S, Rougraff BT, Davis K. Indeterminate pulmonary nodules in patients with sarcoma affect survival. Clin Orthop Relat Res 2007;459:118-21.
56. Cho HS, Park IH, Jeong WJ, Han I, Kim HS. Prognostic value of computed tomography for monitoring pulmonary metastases in soft tissue sarcoma patients after surgical management: a retrospective cohort study. Ann Surg Oncol 2011;18:3392-8.
57. Whooley BP, Gibbs JF, Mooney MM, McGrath BE, Kraybill WG. Primary extremity sarcoma: what is the appropriate follow-up? Ann Surg Oncol 2000;7:9-14.
58. Bertrand TE, Cruz A, Binitie O, Cheong D, Letson GD. Do Surgical Margins Affect Local Recurrence and Survival in Extremity, Nonmetastatic, High-grade Osteosarcoma? Clin Orthop Relat Res 2016;474:677-83.
59. Kasalak O, Dammann A, Adams HJA, et al. Surveillance MRI for the detection of locally recurrent Ewing sarcoma seems futile. Skeletal Radiol 2018;47:1517-22.
60. Takeuchi A, Lewis VO, Satcher RL, Moon BS, Lin PP. What are the factors that affect survival and relapse after local recurrence of osteosarcoma? Clin Orthop Relat Res 2014;472:3188-95.
61. Wasilewski-Masker K, Liu Q, Yasui Y, et al. Late recurrence in pediatric cancer: a report from the Childhood Cancer Survivor Study. J Natl Cancer Inst 2009;101:1709-20.
62. Bacci G, Longhi A, Ferrari S, et al. Pattern of relapse in 290 patients with nonmetastatic Ewing's sarcoma family tumors treated at a single institution with adjuvant and neoadjuvant chemotherapy between 1972 and 1999. Eur J Surg Oncol 2006;32:974-9.
63. Greenberg DD, Crawford B. Surveillance Strategies for Sarcoma: Results of a Survey of Members of the Musculoskeletal Tumor Society. Sarcoma 2016;2016:8289509.
64. Sharma P, Khangembam BC, Suman KC, et al. Diagnostic accuracy of 18F-FDG PET/CT for detecting recurrence in patients with primary skeletal Ewing sarcoma. Eur J Nucl Med Mol Imaging 2013;40:1036-43.
65. Vadi SK, Mittal BR, Gorla AKR, et al. 18F-FDG PET/CT in Diagnostic and Prognostic Evaluation of Patients With Suspected Recurrence of Chondrosarcoma. Clin Nucl Med 2018;43:87-93.
66. Chang KJ, Kong CB, Cho WH, et al. Usefulness of increased 18F-FDG uptake for detecting local recurrence in patients with extremity osteosarcoma treated with surgical resection and endoprosthetic replacement. Skeletal Radiol 2015;44:529-37.
67. Diana Afonso P, Kosinski AS, Spritzer CE. Following unenhanced MRI assessment for local recurrence after surgical resection of mesenchymal soft tissue tumors, do additional gadolinium-enhanced images change reader confidence or diagnosis? Eur J Radiol 2013;82:806-13.
68. Kransdorf MJ, Murphey MD. The use of gadolinium in the MR evaluation of soft tissue tumors. Semin Ultrasound CT MR 1997;18:251-68.
69. Gronchi A, Lo Vullo S, Colombo C, et al. Extremity soft tissue sarcoma in a series of patients treated at a single institution: local control directly impacts survival. Ann Surg 2010;251:506-11.
70. Novais EN, Demiralp B, Alderete J, Larson MC, Rose PS, Sim FH. Do surgical margin and local recurrence influence survival in soft tissue sarcomas? Clin Orthop Relat Res 2010;468:3003-11.
71. Sabolch A, Feng M, Griffith K, et al. Risk factors for local recurrence and metastasis in soft tissue sarcomas of the extremity. Am J Clin Oncol 2012;35:151-7.
72. Salas S, Stoeckle E, Collin F, et al. Superficial soft tissue sarcomas (S-STS): a study of 367 patients from the French Sarcoma Group (FSG) database. Eur J Cancer 2009;45:2091-102.
73. Sugiura H, Nishida Y, Nakashima H, Yamada Y, Tsukushi S, Yamada K. Surgical procedures and prognostic factors for local recurrence of soft tissue sarcomas. J Orthop Sci 2014;19:141-9.
74. Alamanda VK, Crosby SN, Archer KR, Song Y, Schwartz HS, Holt GE. Predictors and clinical significance of local recurrence in extremity soft tissue sarcoma. Acta Oncol 2013;52:793-802.
75. Stojadinovic A, Leung DH, Allen P, Lewis JJ, Jaques DP, Brennan MF. Primary adult soft tissue sarcoma: time-dependent influence of prognostic variables. J Clin Oncol 2002;20:4344-52.
76. Rothermundt C, Whelan JS, Dileo P, et al. What is the role of routine follow-up for localised limb soft tissue sarcomas? A retrospective analysis of 174 patients. Br J Cancer 2014;110:2420-6.

77. Park JW, Yoo HJ, Kim HS, et al. MRI surveillance for local recurrence in extremity soft tissue sarcoma. Eur J Surg Oncol 2019;45:268-74.
78. Sawamura C, Matsumoto S, Shimoji T, Okawa A, Ae K. How long should we follow patients with soft tissue sarcomas? Clin Orthop Relat Res 2014;472:842-8.
79. Al-Ibraheem A, Buck AK, Benz MR, et al. (18) F-fluorodeoxyglucose positron emission tomography/computed tomography for the detection of recurrent bone and soft tissue sarcoma. Cancer 2013;119:1227-34.
80. Park SY, Chung HW, Chae SY, Lee JS. Comparison of MRI and PET-CT in detecting the loco-regional recurrence of soft tissue sarcomas during surveillance. Skeletal Radiol 2016;45:1375-84.
81. Erfanian Y, Grueneisen J, Kirchner J, et al. Integrated 18F-FDG PET/MRI compared to MRI alone for identification of local recurrences of soft tissue sarcomas: a comparison trial. Eur J Nucl Med Mol Imaging 2017;44:1823-31.
82. Richardson K, Potter M, Damron TA. Image intensive soft tissue sarcoma surveillance uncovers pathology earlier than patient complaints but with frequent initially indeterminate lesions. J Surg Oncol 2016;113:818-22.
83. Labarre D, Aziza R, Filleron T, et al. Detection of local recurrences of limb soft tissue sarcomas: is magnetic resonance imaging (MRI) relevant? Eur J Radiol 2009;72:50-3.
84. Tagliafico A, Truini M, Spina B, et al. Follow-up of recurrences of limb soft tissue sarcomas in patients with localized disease: performance of ultrasound. Eur Radiol 2015;25:2764-70.
85. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf. Accessed March 31, 2022.

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.