American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Follow-up of Malignant or Aggressive Musculoskeletal Tumors**

Variant 1: **Lower-risk patient (low grade). Evaluation for metastatic disease to the lung from musculoskeletal primary.**

Radiologic Procedure	Rating	Comments	RRL*
Modality for Baseline Examination			
CT chest without contrast	9	Despite some of the cost analysis studies, the panel believes early diagnosis of lung metastases is critical and that chest CT should be performed. If chest CT is done, chest x-ray is not necessary.	☢ ☢ ☢
FDG-PET/CT whole body	5	In individual cases, can be a good problem-solving tool. Outcomes data on FDG-PET/CT are pending. The CT portion of FDG-PET/CT, although unenhanced, can include thin-section images through the whole body, which can enhance diagnosis.	☢ ☢ ☢ ☢
X-ray chest	3		☢
CT chest with contrast	1		☢ ☢ ☢
CT chest without and with contrast	1		☢ ☢ ☢
Modality for Follow-Up Examination			
CT chest without contrast	9		☢ ☢ ☢
FDG-PET/CT whole body	4	Can be a useful problem-solving tool if another study is equivocal.	☢ ☢ ☢ ☢
X-ray chest	3		☢
CT chest with contrast	1		☢ ☢ ☢
CT chest without and with contrast	1		☢ ☢ ☢
Timing of First Postoperative Examination			
3-6 months postoperative	9		Varies
Frequency of Follow-Up			
Every 3-6 months	9		Varies
Every 6-12 months	2		Varies
Duration of Follow-Up			
10 years	9	After 5 years, frequency can decrease to every 6-12 months.	Varies
5 years	2		Varies
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Clinical Condition: **Follow-up of Malignant or Aggressive Musculoskeletal Tumors**

Variant 2: **Higher-risk patient (high grade). Evaluation for metastatic disease to the lung from musculoskeletal primary.**

Radiologic Procedure	Rating	Comments	RRL*
Modality for Baseline Examination			
CT chest without contrast	9	Despite some of the cost analysis studies, the panel believes early diagnosis of lung metastases is critical and that chest CT should be performed. If chest CT is done, chest x-ray is not necessary.	☢☢☢
FDG-PET/CT whole body	7	In individual cases, can be a good problem-solving tool. FDG-PET/CT appears to be emerging as a primary diagnostic tool as well for diagnosing metastatic disease in many musculoskeletal tumors.	☢☢☢☢
X-ray chest	2		☢
CT chest with contrast	1		☢☢☢
CT chest without and with contrast	1		☢☢☢
Modality for Follow-Up Examination			
CT chest without contrast	9		☢☢☢
FDG-PET/CT whole body	5	Can be a useful problem-solving tool if another study is equivocal.	☢☢☢☢
X-ray chest	2		☢
CT chest with contrast	1		☢☢☢
CT chest without and with contrast	1		☢☢☢
Timing of First Postoperative Examination			
3-6 months postoperative	9		Varies
Frequency of Follow-Up			
Every 3-6 months	9		Varies
Every 6-12 months	2		Varies
Duration of Follow-Up			
10 years	9	After 5 years, frequency can decrease to every 6-12 months.	Varies
5 years	2		Varies

Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate**

***Relative Radiation Level**

Clinical Condition: **Follow-up of Malignant or Aggressive Musculoskeletal Tumors**

Variant 3: **Evaluation for osseous metastatic disease from musculoskeletal primary.**

Radiologic Procedure	Rating	Comments	RRL*
Timing of Baseline Examination			
Only if symptomatic	9	Although additional imaging should be provided only if the patient is symptomatic, it should be noted that in many cases, baseline whole-body FDG-PET/CT or MRI would already have been done, which provides high sensitivity for some bone tumors.	Varies
Frequency of Follow-Up			
Only if symptomatic	9		Varies
Duration of Follow-Up			
Only if symptomatic	9		Varies
Modality for Follow-up Examination			
FDG-PET/CT whole body	7	In individual cases, can be a good problem-solving tool. Sclerotic lesions are more difficult to detect with PET but are well demonstrated on the CT portion of the FDG-PET/CT examination.	☢ ☢ ☢ ☢
Tc-99m bone scan whole body	5	Useful screening tool. In cases of abnormal spine uptake, SPECT/CT can be used to better distinguish metastases from degenerative changes.	☢ ☢ ☢
MRI whole body without contrast	5	Has demonstrated superior sensitivity and diagnostic accuracy compared to FDG-PET/CT. The value of this modality must be balanced against the time necessary to accomplish the study and the inconsistent availability of the expertise needed to interpret it.	O
MRI whole body without and with contrast	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: **Follow-up of Malignant or Aggressive Musculoskeletal Tumors**

Variant 4: **Surveillance for local recurrence.**

Radiologic Procedure	Rating	Comments	RRL*
Timing of Baseline Exams			
3-6 months postoperative	9		Varies
Frequency of Follow-Up			
At 3 months or before 6 months	9		Varies
At 6 months or before 9 months	2		Varies
At 9 months or before 12 months	2		Varies
Duration of Follow-Up			
10 years	9	After 5 years, frequency can decrease to every 12 months, or the follow-up can be performed earlier if symptomatic.	Varies
3 years	1		Varies
5 years	1		Varies
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Variant 5: **Osseous tumor, without significant hardware present. Local recurrence.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray area of interest	9	Both MRI and x-ray are indicated.	Varies
MRI area of interest without and with contrast	9	Both MRI and x-ray are indicated. Contrast administration is helpful for further evaluation of equivocal findings. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI area of interest without contrast	8	Both MRI and x-ray are indicated.	O
FDG-PET/CT whole body	4	Can be a useful problem-solving tool if another study is equivocal.	☢☢☢☢
CT area of interest without contrast	4	On a case-by-case basis, CT may be useful. Useful for osseous tumors when better definition of bony anatomy is needed.	Varies
CT area of interest without and with contrast	4		Varies
CT area of interest with contrast	3		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: **Follow-up of Malignant or Aggressive Musculoskeletal Tumors**

Variant 6: **Osseous tumor, with significant hardware present. Local recurrence.**

Radiologic Procedure	Rating	Comments	RRL*
X-ray area of interest	9		Varies
MRI area of interest without contrast	7	Can use metal suppression techniques.	O
MRI area of interest without and with contrast	7	Can use metal suppression techniques. Contrast administration is helpful for further evaluation of equivocal findings. Since fat suppression is inhomogeneous with adjacent hardware, pre- and post-contrast subtraction postprocessing is recommended. See statement regarding contrast in text under "Anticipated Exceptions."	O
FDG-PET/CT whole body	5	Can be a useful problem-solving tool if another study is equivocal.	☢☢☢☢
CT area of interest without contrast	5	Can be useful if MRI not informative. Alter technique to decrease metal artifact.	Varies
CT area of interest with contrast	5		Varies
CT area of interest without and with contrast	2		Varies
US area of interest	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Variant 7: **Soft-tissue tumors; presume no significant hardware. Local recurrence.**

Radiologic Procedure	Rating	Comments	RRL*
MRI area of interest without and with contrast	9	Contrast administration is helpful for further evaluation of equivocal findings. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRI area of interest without contrast	8		O
FDG-PET/CT whole body	6	Can be a useful problem-solving tool if another study is equivocal. Outcomes data on FDG-PET/CT are pending. The CT portion of FDG-PET/CT includes thin-section images through the whole body, which can enhance diagnosis.	☢☢☢☢
CT area of interest with contrast	6		Varies
US area of interest	4		O
X-ray area of interest	2	Problem solver if needed to interpret findings on MRI.	Varies
CT area of interest without contrast	2	Postoperative scarring can obscure local recurrence.	Varies
CT area of interest without and with contrast	2		Varies
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

FOLLOW-UP OF MALIGNANT OR AGGRESSIVE MUSCULOSKELETAL TUMORS

Expert Panel on Musculoskeletal Imaging: Jeffrey J. Fitzgerald, MD[1]; Catherine C. Roberts, MD[2]; Richard H. Daffner, MD[3]; Barbara N. Weissman, MD[4]; Marc Appel, MD[5]; Laura Bancroft, MD[6]; D. Lee Bennett, MD, MA[7]; Judy S. Blebea, MD[8]; Michael A. Bruno, MD[9]; Ian Blair Fries, MD[10]; Isabelle M. Germano, MD[11]; Curtis W. Hayes, MD[12]; Langston Holly, MD[13]; Mark J. Kransdorf, MD[14]; Jonathan S. Luchs, MD[15]; William B. Morrison, MD[16]; Jeffrey J. Olson, MD[17]; Stephen C. Scharf, MD[18]; David W. Stoller, MD[19]; Mihra S. Taljanovic, MD[20]; Michael J. Tuite, MD[21]; Robert J. Ward, MD[22]; James N. Wise, MD[23]; Adam C. Zoga.[24]

Summary of Literature Review

This topic specifically excludes: 1) metastatic disease from other primaries; 2) head and neck tumors; 3) spine tumors; 4) chest wall tumors; 5) multiple myeloma; 6) benign or nonaggressive bone or soft-tissue tumors; and 7) evaluation for chemotherapy or radiation therapy effectiveness, preoperatively after such induction therapy.

It should be noted that there are no controlled studies in the literature that directly address the issue of tumor follow-up, and the recommendations here are based mostly on consensus, are subject to change if new data come out, and should be used only as a guideline, with generous opportunity for modification in individual circumstances.

This topic addresses two issues regarding follow-up for tumor therapy: the timing of the follow-up examination, and the type of imaging best used.

Ideally, the timing of follow-up for tumor recurrence or metastatic disease would be individualized for each tumor type and each patient. To design a follow-up protocol, one would generally wish to know the following: 1) How good is the imaging test to be used for detecting the presence of tumor? 2) How important is early detection of relapse in relation to salvage effectiveness (utility/risk analysis)? and 3) When is the relapse most likely to occur (hazard rate)? Individual hazard rate is related to tumor type, grade, size, and central location; patient age and gender; tumor stage; type of treatment; and surgical margins. Overall, the goal of an imaging protocol is to concentrate testing when the relapse is most likely to occur. This presumes that testing frequency should gradually decrease over time. There are outstanding reviews of model development for such protocols in lymphoma and other tumors [1,2]. However, such models do not exist for extremity tumors.

Because models relating to the hazard rate and utility/risk analysis do not exist for individual extremity tumor types, we will consider the sarcomas as a group and try to evaluate general local recurrence rate and timing as well as metastatic rate and timing. The most helpful general information can be found in several articles [3-8]. The information most commonly agreed to among these authors is that approximately 80% of patients who recur locally or systemically will do so within 2 years of their primary treatment. This suggests that the most aggressive follow-up should occur in the first 2 years, with tapering of imaging after that time.

Timing and Frequency of Follow-Up

The incidence of metastatic disease varied considerably in the large studies cited above. The incidence of metastatic disease only to the lung ranged from 18%-52% [4,6]. In one study, 31% of patients had metastatic disease, of whom 42% previously had a local recurrence [7]. In at least some of these studies, it appears as though the incidence of local recurrence is less frequent than the occurrence of metastatic disease in high-grade sarcomas.

[1]Research Author, Mayo Clinic, Phoenix, Arizona. [2]Principal Author, Mayo Clinic, Phoenix, Arizona. [3]Panel Chair, Allegheny General Hospital, Pittsburgh, Pennsylvania. [4]Panel Vice-chair, Brigham & Women's Hospital, Boston, Massachusetts. [5]Warwick Valley Orthopedic Surgery, Warwick, New York, American Academy of Orthopaedic Surgeons. [6]Florida Hospital, Orlando, Florida. [7]University of Iowa Roy J and Lucille A Carver College of Medicine, Iowa City, Iowa. [8]Cleveland Clinic, Cleveland, Ohio. [9]Penn State Milton S. Hershey Medical Center, Hershey, Pennsylvania. [10]Bone, Spine and Hand Surgery, Chartered, Brick, NJ, American Academy of Orthopaedic Surgeons. [11]Mount Sinai School of Medicine, New York, New York, American Association of Neurological Surgeons/Congress of Neurological Surgeons. [12]VCU Health System, Richmond, Virginia. [13]University of California-Los Angeles Medical Center, Los Angeles, California, American Association of Neurological Surgeons/Congress of Neurological Surgeons. [14]Mayo Clinic, Jacksonville, Florida. [15]Winthrop University Hospital, Mineola, New York. [16]Thomas Jefferson University Hospital, Philadelphia, Pennsylvania. [17]Emory University, Atlanta, Georgia, American Association of Neurological Surgeons/Congress of Neurological Surgeons. [18]Lenox Hill Hospital, New Rochelle, New York, Society of Nuclear Medicine. [19]California Pacific Medical Center, San Francisco, California. [20]University of Arizona Health Sciences Center, Tucson, Arizona. [21]University of Wisconsin Hospital, Madison, Wisconsin. [22]Tufts Medical Center, Boston, Massachusetts. [23]University of Kentucky, Lexington, Kentucky. [24]Thomas Jefferson University, Philadelphia, Pennsylvania.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply individual or society endorsement of the final document.

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

Therefore, local failure may not be the initiating factor in most systemic metastases. This finding suggests that follow-up studies should include systemic surveillance as well as imaging for local recurrence.

Of the systemic metastases, lung metastasis is by far the most frequent. It is generally accepted that computed tomography (CT) is more accurate in diagnosing lung parenchymal metastatic disease than is chest radiography [9]. However, that increased accuracy may not translate to a positive cost-benefit analysis. One excellent review article quotes a retrospective study of 125 consecutive patients in which, for low-risk patients (primary tumor <5 cm), the incremental cost was $59,722 per case of synchronous pulmonary metastases when chest CT was added to chest radiography. This suggested to the authors that the yield for an added CT scan is low when a good-quality chest radiograph does not reveal any suspicion of lung metastases [3]. Based on this finding, those authors recommend surveillance for lung metastases in the low-risk patient (primary tumor <5 cm) by chest radiography alone. In the high-risk category (primary tumor >5 cm), the study found that initial staging chest CT was cost-effective, but it recommended follow-up only by chest radiography [3]. However, given the higher accuracy of CT, as well as the fact that pulmonary metastases from sarcomas are frequently cured by surgical excision, it is likely that the use of CT for staging and surveillance for lung metastases will continue.

In terms of frequency of follow-up, some experts recommend that high-risk patients be followed with chest radiography every 3 months for 2 years, every 4 months for the next 2 years, every 6 months for the fifth year, and annually after that [3]. The recommendation from another review based on the experiences of two large tumor centers for low-risk patients is similar, calling for chest radiograph for pulmonary metastatic surveillance every 3-4 months for 2 years, every 4-6 months for the next 2 years, and yearly after that [10]. Six-month imaging is widely regarded by other experts as a suitable compromise between intense surveillance and early lesion detection [11]. The optimal frequency and modality of follow-up imaging have not been scientifically established.

The frequency of other distant metastatic disease ranges from 14%-20%. It is debatable whether surveillance for osseous metastases or lymphatic metastatic disease is cost-efficient. If required, technetium bone scan is most frequently used; with care, whole-body magnetic resonance imaging (MRI) can detect osseous metastases with reasonable sensitivity and specificity [12,13]. Opposed phase gradient echo sequences may be used to improve specificity when equivocal marrow changes are seen on MRI [14].

The use of 2-fluorine-18 fluoro-2-deoxy-D-glucose (FDG) positron emission tomography (PET) CT has been shown to be effective in localizing metastases from many bone sarcomas, though it may be nonspecific and produces false negatives in osteosarcoma bone metastases [15-18]. Although bone scan, FDG-PET/CT, and MRI may detect osseous metastases, these studies are generally not advocated as part of the initial workup or follow-up for osseous metastases in asymptomatic cases.

Metastatic disease from primary extremity liposarcoma deserves special note. A study retrospectively looking at 122 patients with extremity liposarcoma found that the myxoid type (86% of liposarcomas in this series) tended to metastasize to extrapulmonary sites, frequently involving the trunk or retroperitoneum [10]. Thus, a biopsy-proven primary myxoid liposarcoma in the trunk or retroperitoneum should prompt a rigorous search for an occult extremity primary. A subsequent prospective study following 230 patients with myxoid liposarcoma showed that the great majority of patients who developed metastatic disease had a bone metastasis as their first metastatic focus. Of these, the vast majority were in the spine [19]. Thus it seems reasonable that screening MRI of the spine be performed in patients newly diagnosed with or being followed for a myxoid liposarcoma.

Local recurrence can be as low as 10%-20% using multimodality therapy as well as limb-sparing surgery [6] and may be routinely as low as 10% in patients with high-grade sarcomas <5 cm at the time of diagnosis. Local recurrence ranged from 20%-52% in the two largest studies [4,6]. Different studies have related local failure to tumor grade and size as well as to type of resection [6]. A multivariate analysis of 15 factors demonstrated marginal excision, tumor necrosis, and extracompartmental location to be the greatest factors relating to local recurrence, but the greatest factors relating to survival include local recurrence, high grade, male gender, and extensive necrosis [5]. Stotter et al [7] found that local recurrence does not correlate with tumor size, although metastatic disease does. Similarly, local recurrence does not correlate with location proximal to the original tumor or grade, but the likelihood of metastatic disease does. Local recurrence in this study related most strongly to the "quality" of local treatment. In another study, long-term survival was influenced only by positive surgical margins [20]. Another study noted specifically that, compared with ablative surgical procedure, limb-sparing surgery itself has a three- to five-fold increased risk of local relapse, which significantly worsens the prognosis [15].

Because of the different findings, it seems reasonable to establish a routinely suggested timing sequence for evaluating local recurrence, with the caveat that for marginal excision, in the presence of large regions of necrosis and high-grade tumor or site evaluation, more frequent follow-up may be efficacious. One retrospective analysis drawing on a review of 1,500 patients from the Memorial Sloan-Kettering Cancer Center and the M.D. Anderson Cancer Center, recommended follow-up of adult soft-tissue sarcomas [3] based on low and high risk of recurrence. Risk stratification was based on size of primary neoplasm (T1: low risk <5 cm; T2: high risk >5 cm). For local recurrence in low-risk patients the recommendation was for "cross-sectional imaging of choice" individualized for patient and location of primary tumor. The implication is that for extremity primaries the clinical examination may obviate the need for routine cross-sectional imaging follow-up in the low-risk group. Cross-sectional imaging follow-up for less accessible areas (trunk or retroperitoneum) would be required at 3-4-month intervals for 2 years, 4-6-month intervals for 2 years, and yearly thereafter. Within the low-risk group, surveillance could stop after 5-10 years.

Within the high-risk group local recurrence rate was noticeably higher, and the analysis recommended cross-sectional imaging every 3 months for 2 years, every 4 months for the next 2 years, every 6 months for the fifth year, and then annually [3]. A study looking at long-term follow-up (>5 years) of patients with primary extremity sarcoma [20] showed that 21% of patients alive at 5 years will die of their disease in the next 5 years. In a multifactorial analysis, a positive surgical margin was the only factor that showed positive predictive value for long-term recurrence. Size, grade, age, and depth were not shown to increase long-term recurrence, and local recurrence did not correlate with increased mortality after 5 years. These data may necessitate a more tailored approach to follow-up of patients with bone or soft-tissue sarcoma. Patients with T2 primaries need to be followed more closely than those with T1 primaries, and those with positive surgical margins may need longer surveillance than those with complete excision.

Implications of Tumor Type and Therapy

The specific type of imaging for follow-up to check for local recurrence will depend on the site of the original tumor (osseous vs soft tissue), as well as the type of therapy used (curettage with bone graft vs resection with allograft vs soft-tissue resection, all taking into account the presence or absence of hardware) [21-23]. The following comments relate to each of these situations.

One reference suggests that patients treated with curettage and bone chip allografts can be followed by MRI [24]. It suggests that most cases will have a speckled bright signal on T2 imaging and that if signal intensity on both T1 and T2 imaging is predominantly low, there is a reasonable likelihood that this does not represent recurrence. Richardson et al [25] discuss MRI follow-up of patients with curettage and bone grafting plus cryosurgery. Many of these cases showed a zone beyond the surgical margins that is low signal on T1 and high signal on T2, the thickness of which ranges from 1 to 17 mm, varying within a single patient.

The evaluation of large allografts used in treating sarcomas is discussed in several articles [24,26-30]. Most of these studies used only radiographs [24,26,27,30]. They indicate that there is a high complication rate (40%-57%). The complications include infection (6%-25%), usually occurring in the first 12 months; the patient may present with a mass. Fracture is a common complication as well, ranging from 15%-27% and occurring in the first 3 years. Tumor recurrence in these series ranged from 0%-16% and generally occurred in 12-24 months. After 4 years, there is late development of articular degeneration if the graft is an osteoarticular type. Technetium bone scanning may reflect the physiology of allograft incorporation [31,32], but it has not been advocated to detect local recurrence. Also, specific CT appearance is described, showing initial thinning of the cortex and very prominent subcortical cyst formation as well as a differential in attenuation between the graft and host bone [33].

One extremely small study of MRI of allografts showed a very heterogeneous T1 and T2 signal but was inadequate in scope for further information to be derived. It seems that radiographs are usually used for follow-up of massive allografts because of the large amount of hardware that is generally present. However, the authors noted that multislice CT with reformatting in coronal or sagittal planes can minimize metallic artifact and can be extremely useful in evaluating for either union or allograft to host bone or for osseous complications. Most of the complications relate to failure of the graft or infection.

Recurrence involving only the soft tissues could be detected by ultrasound (US) if too much hardware is present to evaluate with other imaging modalities. FDG-PET/CT has emerged as a powerful tool for evaluating local recurrence in the face of suboptimal cross-sectional imaging because of large amounts of metal. FDG-PET/CT and its possible applications are addressed separately below.

Magnetic Resonance Imaging, Computed Tomography, and Ultrasound

Three studies evaluated MRI of both soft tissue and bone tumors in follow-up [33-35]. The studies emphasized that high signal intensity on T2 can be seen for a number of non-neoplastic reasons. These include presence of a postoperative seroma, hematoma, changes related to radiation therapy, fat necrosis, packing material, allograft, scar tissue, and bowel or bladder herniation. Although the timing of the study and knowledge of details of the case can be very valuable in sorting out these possibilities, in some cases they did not obviate biopsy [33]. The larger of the studies [34], with 60 patients in follow-up, showed that if there is a lesion of low signal intensity on T2, it generally does not represent recurrent tumor (sensitivity 96%). If there is a lesion with high signal intensity on T2 and surgery was the only therapy used, tumor recurrence is a high likelihood. If radiation therapy as well as surgery has been used, high signal intensity is nonspecific for distinguishing between radiation-induced inflammation and recurrent tumor. In that study, 66% of patients had high signal intensity on T2, and the overall sensitivity for detecting tumor recurrence was only 70%.

In evaluating whether CT or MRI is more efficacious in follow-up of sarcomas, one should discount the Radiology Diagnostic Oncology Group® (RDOG®) report in which no statistical difference was found between CT and MRI in determining tumor involvement of bone, muscle, joints, or neurovascular structures because this study did not address questions of follow-up [32]. However, one study demonstrated that CT does not differentiate between tumor recurrence and scar, since both enhance [36].

Few studies advocate the use of US in follow-up for soft-tissue masses. A study performed in 1991 compared MRI and US in follow-up of soft-tissue sarcoma [37]. The sensitivity and specificity of MRI for local recurrence were 83% and 93%, respectively, while those for US were 100% and 79%, respectively. These differences were not statistically significant. It was noted that acute postoperative changes make US diagnosis difficult (particularly in the first 3-6 months postoperatively). Note was also made that US may be particularly helpful in detecting recurrences that have short T2 relaxation times. This particular article recommends baseline US and MRI, followed by US. If subsequent US scans are inconclusive, MRI with contrast is recommended.

The findings of these and other articles are difficult to apply, as MRI has dramatically improved over the years since the studies were performed. Another article [38] is biased, without cross-sectional imaging comparison but with favorable statistics on a prospective study of 50 consecutive patients with clinical suspicion of local recurrence. Twenty-four of 26 patients were confirmed as having recurrence, and 22 of 22 were accurately classified as no recurrence or benign masses (abscesses or lipoma) based on US examination. Discrete, hypoechoic, well-defined lesions were labeled as recurrence. Although these studies did not include osseous sarcoma follow-up, US in the presence of extensive hardware may be useful for follow-up for soft-tissue mass in that situation. Color Doppler flow imaging may also help differentiate recurrent tumor mass from fibrous tissue or other nonvascular tissue in the postoperative tumor site; this may be particularly helpful in the presence of hardware and if there is a baseline postoperative Doppler study [39]. These problem-solving utilities of US are useful in the absence of FDG-PET/CT.

Several MRI studies have refined the methodology for evaluation and for detecting recurrence of soft-tissue sarcomas [31,39,40]. On the basis of a large number of examinations (511 examinations, 182 patients), Vanel et al [40] showed that of the 102 examinations showing no high-signal-intensity mass, 101 had no recurrence. Seventy-nine of the patients had a high signal intensity in the surgical bed on T2 but no mass; of these, only two had a local recurrence. Seventy-eight patients had high signal intensity on T2 with the presence of a mass. Sixty of these were proven to have recurrence, 24 had a seroma, and four had a radiation-induced pseudomass. Further evaluation with contrast showed that seromas do not enhance, whereas recurrences and radiation changes do enhance. A caveat here is that if there is a large area of necrosis, then tumor may not enhance. It was also noted that generally (with some areas of overlap), recurrences enhance earlier in a dynamic study than does a radiation-induced pseudomass. Another report suggested that in regions of high signal intensity on T2-weighted imaging, T1-weighted images should be reviewed for normal “texture” of muscle to help differentiate recurrence from other etiologies of high signal intensity.

Very few follow-up protocols have been advocated. However, Vanel et al [39] suggest an algorithm for following soft-tissue tumors postoperatively. This algorithm starts with T2 imaging. If a mass is present on T2-weighted imaging, it should be followed by T1-weighted sequences with and without contrast. This procedure generally distinguishes hematoma and seroma from tumor or inflammation. If necessary, this procedure can be followed by dynamic enhanced imaging with subtraction postprocessing, which further helps differentiate tumors from

inflammation. In this algorithm, if a region of high signal intensity is seen on T2-weighted imaging but there is no mass present; further evaluation with contrast imaging is not recommended. Reasonably enough, it is stated that there will be some exceptions to the above recommendations. This algorithm is supported by a recent article reporting on 98 patients with seven local recurrences and three inflammatory pseudotumors [41]. All but one recurrence was detected by T2-weighted imaging, indicating that it is a logical way to start the examination. Although enhanced MRI with subtraction postprocessing characterizes recurrences better than routine sequences in most patients, it is advocated only if contrast injection is required for diagnosis [41]. Contrast may be particularly helpful when assessing for recurrence in the presence of postoperative hematoma [42]. Based on these authors' experience, they advocate delaying the postoperative baseline scan for at least 6-8 weeks to allow postoperative changes to subside; they acknowledge that 3- or 6-month follow-up MRI examinations may be too costly but reiterate that close follow-up is mandatory, especially if the surgical resection was intralesional or marginal [43].

With regard to screening for osseous metastases, Schmidt et al [13] showed that coronal whole-body and sagittal spine MRI using T1 weighted and short tau inversion recovery (STIR) sequences was superior to FDG-PET/CT in sensitivity and diagnostic accuracy. Thus, in centers that have this capability, this is a good alternative to PET/CT and has the added benefit of no ionizing radiation.

Tc-99m Whole-Body Bone Scan

There is a paucity of recent literature regarding whole-body bone scan and screening for osseous metastases. Much of this likely relates to recent advances in FDG-PET/CT and whole-body MRI and their superior anatomic resolution and specificity. Nonetheless, whole-body bone scan remains a useful screening tool in osseous metastatic disease, with an overall sensitivity comparable to that of FDG-PET/CT [44]. In cases where there is abnormal radiotracer uptake in the spine, SPECT/CT can be used to better distinguish metastases from degenerative changes, thus increasing specificity [45].

FDG-PET/CT

There has been a significant amount of literature exploring the utility of FDG-PET/CT in evaluating recurrent soft-tissue and osseous sarcoma [15-18,46-51]. The literature seems to support using FDG-PET/CT in three scenarios: 1) as a problem-solving tool in equivocal cases of local recurrence detected by MRI in patients who have undergone limb salvage surgery and have postoperative and/or radiation change confounding accurate MRI assessment, 2) as a primary evaluation for local recurrence in patients with overwhelming metallic artifact precluding accurate assessment with MRI, and 3) as a confirmatory tool in equivocal cases of distant metastases.

First, FDG-PET/CT has been shown to have a high sensitivity and specificity for local recurrence in those patients in whom postoperative change or significant hardware causes equivocal or nondiagnostic MR findings. For evaluating local recurrence FDG-PET/CT sensitivity ranges from 88%-100% [18,50] and specificity ranges from 92%-100% [18,50]. Specifically in nine patients with equivocal or technically inadequate MRI, sensitivity and specificity were 100% for recurrence using FDG-PET/CT scanning [46]. Situations in which FDG-PET/CT was falsely negative were in tumors of low histologic grade (two low-grade liposarcomas and one low-grade chondrosarcoma), and one false positive was caused by inflammation [51]. Postirradiation or postoperative inflammation did not seem to cause diagnostic difficulty due to significant differences in specific uptake values (SUV) between benign and malignant causes. Mean SUV of malignant recurrence ranged from 3.0-5.0, and benign etiologies ranged from <1-1.35 [18,46,51].

Evaluation of distant metastases with FDG-PET has been compared to technetium bone scanning for osseous metastases [17,44] and osseous recurrence [48], and to CT for lung metastases [16]. For Ewing's sarcoma bony metastases (n=49) FDG-PET showed a sensitivity and specificity of 100% and 96%, respectively, compared to 71% and 92% for technetium bone scan [17]. Interestingly, FDG-PET was falsely negative in all six osteosarcoma bony metastases [17]. This was in contrast to evaluation of recurrent osteosarcoma [48], which showed PET to be effective (n=6) in correctly identifying these lesions. FDG-PET failed to equal CT in sensitivity for pulmonary metastases [16], but there were no PET-positive lesions that were CT negative, implying that FDG-PET could be used to confirm lesions suspicious by CT.

It should be noted that the literature cited above is for FDG-PET and not combined FDG-PET/CT. Virtually all clinical studies today are done with FDG-PET/CT, which is reasonably expected to be a more powerful tool than either FDG-PET or CT alone, at least for selected musculoskeletal tumors. FDG-PET/CT may eventually rival MRI for local and distant tumor surveillance due to the increased information obtained from thin-slice CT through

the entire body. Potential limitations of the CT portion of a FDG-PET/CT study include lack of intravenous (IV) contrast and lack of breath-hold technique [52]. Bone lesions identified on FDG-PET are not always visible on CT [29,53]. Although FDG-PET/CT has a high positive predictive value when findings are concordant, the positive predictive value has been shown to markedly decrease when findings are discordant [54]. Additional outcomes data for FDG-PET/CT are expected in the future as a result of the National Oncologic PET Registry (www.cancerpetregistry.org).

In summary, FDG-PET/CT is an area of robust growth and research, with current evidence supporting its use as a problem- solving tool in equivocal cases of local or distant recurrence detected on MRI or CT. In addition it may have high utility in evaluating tumor recurrence in patients with orthopedic hardware that limits accurate use of MRI or CT. Low sensitivity for low-grade neoplasms and insensitivity for bony metastases of osteosarcoma are exceptions that need to be considered by the interpreting and ordering physician. Routine use of FDG-PET/CT beyond a problem-solving role has not been widely advocated in the literature, though anecdotal experiences are increasing rapidly. The panel feels that this emerging technology deserves recognition as a problem-solving tool and as a primary diagnostic tool for metastatic lesion detection and surveillance, at least in high-grade musculoskeletal tumors. Furthermore, the results of current studies and recent experience warrant a systematic prospective multicenter evaluation of its clinical value in diagnosis, staging, response to therapy, and detecting recurrence and metastatic disease of bone and soft-tissue sarcomas. Any such study must include its influence on outcome as well as a cost-benefit analysis. The same might be said for much of the other imaging recommended in this document. The desired evidence-based data are difficult to obtain for bone and soft-tissue sarcomas. We therefore strive for a logical consensus that allows for optimizing patient and cost benefit. The result must allow for some nonuniformity, since clinical judgment remains of paramount importance in these cases.

Preface to the Tables of Variants

Musculoskeletal tumor follow-up requires decisions regarding imaging method and timing, when assessing for local recurrence and metastatic disease.

- Variants 1 and 2 address modality and timing of follow-up for metastatic disease to the lung from a musculoskeletal primary (low and high grade, respectively).
- Variant 3 addresses the modality and timing of follow-up for osseous metastatic disease from a musculoskeletal primary.
- Variant 4 addresses the timing of follow-up for local recurrence.
- Variants 5, 6, and 7 address the modality for follow-up in osseous tumors without hardware, osseous tumors with hardware, and soft-tissue tumors, respectively.

Summary

- In patients with a musculoskeletal primary malignancy and either a high or low risk for metastatic disease, surveillance for pulmonary metastases should be performed using a CT scan of the chest without contrast. The baseline postoperative examination should occur within 3-6 months. Additional chest CT scans should be performed every 3-6 months for the first 10 years, although after 5 years a decrease in frequency to every 6-12 months can be considered on an individual basis.
- Osseous metastatic disease from a musculoskeletal primary malignancy should be imaged only if symptomatic. Osseous metastatic disease screening can be considered in patients with myxoid liposarcoma, as these patients have a disproportionately high rate of soft-tissue and bone metastases compared with other musculoskeletal primary neoplasms. Whole-body FDG-PET has proven to be a good problem-solving tool in individual cases.
- Baseline imaging of the tumor area should be performed 3-6 months postoperatively. Follow-up imaging should occur every 3-6 months for 10 years. After 5 years, a decrease in frequency to every 12 months can be considered on an individual basis. Additional imaging should occur earlier if the patient becomes symptomatic.
- For surveillance of osseous tumor local recurrence, without significant hardware present, both radiographs and an MRI with or without contrast of the area of interest are indicated. If significant hardware is present, radiographs should be obtained, and an MRI may be attempted using metal suppression techniques. Whole-body FDG-PET can be a useful problem-solving tool if study findings are equivocal.

- For evaluation of soft-tissue tumor local recurrence, MRI of the area of interest with or without contrast is recommended. Whole-body FDG-PET is useful as a problem-solving tool if MRI is equivocal.

Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (ie, <30 mL/min/1.73m^2), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73m^2. For more information, please see the ACR *Manual on Contrast Media* [55].

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

- ACR Appropriateness Criteria® Overview
- Procedure Information
- Evidence Table

References

1. Chang PJ, Parker BR, Donaldson SS, Thompson EI. Dynamic probabilistic model for determination of optimal timing of surveillance chest radiography in pediatric Hodgkin disease. *Radiology.* 1989;173(1):71-75.
2. Dwyer AJ, Prewitt JM, Ecker JG, Plunkett J. Use of the hazard rate to schedule follow-up exams efficiently. An optimization approach to patient management. *Med Decis Making.* 1983;3(2):229-244.

3. Patel SR, Zagars GK, Pisters PW. The follow-up of adult soft-tissue sarcomas. *Semin Oncol.* 2003;30(3):413-416.
4. Potter DA, Glenn J, Kinsella T, et al. Patterns of recurrence in patients with high-grade soft-tissue sarcomas. *J Clin Oncol.* 1985;3(3):353-366.
5. Rooser B, Attewell R, Berg NO, Rydholm A. Survival in soft tissue sarcoma. Prognostic variables identified by multivariate analysis. *Acta Orthop Scand.* 1987;58(5):516-522.
6. Sauter ER, Hoffman JP, Eisenberg BL. Diagnosis and surgical management of locally recurrent soft-tissue sarcomas of the extremity. *Semin Oncol.* 1993;20(5):451-455.
7. Stotter AT, A'Hern RP, Fisher C, Mott AF, Fallowfield ME, Westbury G. The influence of local recurrence of extremity soft tissue sarcoma on metastasis and survival. *Cancer.* 1990;65(5):1119-1129.
8. Strauss SJ, McTiernan A, Whelan JS. Late relapse of osteosarcoma: implications for follow-up and screening. *Pediatr Blood Cancer.* 2004;43(6):692-697.
9. Pass HI, Dwyer A, Makuch R, Roth JA. Detection of pulmonary metastases in patients with osteogenic and soft-tissue sarcomas: the superiority of CT scans compared with conventional linear tomograms using dynamic analysis. *J Clin Oncol.* 1985;3(9):1261-1265.
10. Pearlstone DB, Pisters PW, Bold RJ, et al. Patterns of recurrence in extremity liposarcoma: implications for staging and follow-up. *Cancer.* 1999;85(1):85-92.
11. Bearcroft PW, Davies AM. Follow-up of musculoskeletal tumours. 2. Metastatic disease. *Eur Radiol.* 1999;9(2):192-200.
12. Frat A, Agildere M, Gencoglu A, et al. Value of whole-body turbo short tau inversion recovery magnetic resonance imaging with panoramic table for detecting bone metastases: comparison with 99MTc-methylene diphosphonate scintigraphy. *J Comput Assist Tomogr.* 2006;30(1):151-156.
13. 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(4):939-949.
14. Disler DG, McCauley TR, Ratner LM, Kesack CD, Cooper JA. In-phase and out-of-phase MR imaging of bone marrow: prediction of neoplasia based on the detection of coexistent fat and water. *AJR Am J Roentgenol.* 1997;169(5):1439-1447.
15. Brenner W, Bohuslavizki KH, Eary JF. PET imaging of osteosarcoma. *J Nucl Med.* 2003;44(6):930-942.
16. Franzius C, Daldrup-Link HE, Sciuk J, et al. FDG-PET for detection of pulmonary metastases from malignant primary bone tumors: comparison with spiral CT. *Ann Oncol.* 2001;12(4):479-486.
17. Franzius C, Sciuk J, Daldrup-Link HE, Jurgens H, Schober O. FDG-PET for detection of osseous metastases from malignant primary bone tumours: comparison with bone scintigraphy. *Eur J Nucl Med.* 2000;27(9):1305-1311.
18. Johnson GR, Zhuang H, Khan J, Chiang SB, Alavi A. Roles of positron emission tomography with fluorine-18-deoxyglucose in the detection of local recurrent and distant metastatic sarcoma. *Clin Nucl Med.* 2003;28(10):815-820.
19. Schwab JH, Boland P, Guo T, et al. Skeletal metastases in myxoid liposarcoma: an unusual pattern of distant spread. *Ann Surg Oncol.* 2007;14(4):1507-1514.
20. Lewis JJ, Leung D, Casper ES, Woodruff J, Hajdu SI, Brennan MF. Multifactorial analysis of long-term follow-up (more than 5 years) of primary extremity sarcoma. *Arch Surg.* 1999;134(2):190-194.
21. Jelinek JS, Kransdorf MJ, Moser RP, Temple HT, Lenhart MK, Berrey BH. MR imaging findings in patients with bone-chip allografts. *AJR Am J Roentgenol.* 1990;155(6):1257-1260.
22. Van der Woude HJ, Vanderschueren G. Ultrasound in musculoskeletal tumors with emphasis on its role in tumor follow-up. *Radiol Clin North Am.* 1999;37(4):753-766.
23. Van Laere K, Casier K, Uyttendaele D, et al. Technetium-99m-MDP scintigraphy and long-term follow-up of treated primary malignant bone tumors. *J Nucl Med.* 1998;39(9):1563-1569.
24. Kattapuram SV, Phillips WC, Mankin HJ. Intercalary bone allografts: radiographic evaluation. *Radiology.* 1989;170(1 Pt 1):137-141.
25. Richardson ML, Lough LR, Shuman WP, Lazerte GD, Conrad EU. MR appearance of skeletal neoplasms following cryotherapy. *Skeletal Radiol.* 1994;23(2):121-125.
26. McDonald DJ. Limb-salvage surgery for treatment of sarcomas of the extremities. *AJR Am J Roentgenol.* 1994;163(3):509-513; discussion 514-506.
27. Aho AJ, Ekfors T, Dean PB, Aro HT, Ahonen A, Nikkanen V. Incorporation and clinical results of large allografts of the extremities and pelvis. *Clin Orthop Relat Res.* 1994(307):200-213.

28. Hoeffner EG, Ryan JR, Qureshi F, Soulen RL. Magnetic resonance imaging of massive bone allografts with histologic correlation. *Skeletal Radiol.* 1996;25(2):165-170.
29. Mattila KT, Heikkila JT, Aho AJ, Manner IK, Dean PB. Massive osteoarticular knee allografts: structural changes evaluated with CT. *Radiology.* 1995;196(3):657-660.
30. Patel SR, Miller PR, Gross M, Ryan J. Massive bone allografts for limb salvage. *AJR Am J Roentgenol.* 1997;168(2):543-546.
31. Biondetti PR, Ehman RL. Soft-tissue sarcomas: use of textural patterns in skeletal muscle as a diagnostic feature in postoperative MR imaging. *Radiology.* 1992;183(3):845-848.
32. Panicek DM, Gatsonis C, Rosenthal DI, et al. CT and MR imaging in the local staging of primary malignant musculoskeletal neoplasms: Report of the Radiology Diagnostic Oncology Group. *Radiology.* 1997;202(1):237-246.
33. Panicek DM, Schwartz LH, Heelan RT, Caravelli JF. Non-neoplastic causes of high signal intensity at T2-weighted MR imaging after treatment for musculoskeletal neoplasm. *Skeletal Radiol.* 1995;24(3):185-190.
34. Vanel D, Lacombe MJ, Couanet D, Kalifa C, Spielmann M, Genin J. Musculoskeletal tumors: follow-up with MR imaging after treatment with surgery and radiation therapy. *Radiology.* 1987;164(1):243-245.
35. Garner HW, Kransdorf MJ, Bancroft LW, Peterson JJ, Berquist TH, Murphey MD. Benign and malignant soft-tissue tumors: posttreatment MR imaging. *Radiographics.* 2009;29(1):119-134.
36. Weekes RG, McLeod RA, Reiman HM, Pritchard DJ. CT of soft-tissue neoplasms. *AJR Am J Roentgenol.* 1985;144(2):355-360.
37. Choi H, Varma DG, Fornage BD, Kim EE, Johnston DA. Soft-tissue sarcoma: MR imaging vs sonography for detection of local recurrence after surgery. *AJR Am J Roentgenol.* 1991;157(2):353-358.
38. Arya S, Nagarkatti DG, Dudhat SB, Nadkarni KS, Joshi MS, Shinde SR. Soft tissue sarcomas: ultrasonographic evaluation of local recurrences. *Clin Radiol.* 2000;55(3):193-197.
39. Vanel D, et al. Post treatment assessment of soft tissue tumors. In: DeSchepper AM, Vanhoenacker F, Gielen J, Parizel PM, eds. *Imaging of Soft Tissue Tumors.* 3rd ed. Berlin Heidelberg: Springer Verlag; 2006.
40. Vanel D, Shapeero LG, De Baere T, et al. MR imaging in the follow-up of malignant and aggressive soft-tissue tumors: results of 511 examinations. *Radiology.* 1994;190(1):263-268.
41. Vanel D, Shapeero LG, Tardivon A, Western A, Guinebretiere JM. Dynamic contrast-enhanced MRI with subtraction of aggressive soft tissue tumors after resection. *Skeletal Radiol.* 1998;27(9):505-510.
42. Kransdorf MJ, Murphy MD. Imaging of soft tissue tumors. In: Kransdorf MJ, Murphy MD, eds. *Imaging of soft tissue tumors.* 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2006:38-79.
43. Davies AM, Vanel D. Follow-up of musculoskeletal tumors. I. Local recurrence. *Eur Radiol.* 1998;8(5):791-799.
44. Ito S, Kato K, Ikeda M, et al. Comparison of 18F-FDG PET and bone scintigraphy in detection of bone metastases of thyroid cancer. *J Nucl Med.* 2007;48(6):889-895.
45. Papathanassiou D, Bruna-Muraille C, Jouannaud C, Gagneux-Lemoussu L, Eschard JP, Liehn JC. Single-photon emission computed tomography combined with computed tomography (SPECT/CT) in bone diseases. *Joint Bone Spine.* 2009;76(5):474-480.
46. Bredella MA, Caputo GR, Steinbach LS. Value of FDG positron emission tomography in conjunction with MR imaging for evaluating therapy response in patients with musculoskeletal sarcomas. *AJR Am J Roentgenol.* 2002;179(5):1145-1150.
47. el-Zeftawy H, Heiba SI, Jana S, et al. Role of repeated F-18 fluorodeoxyglucose imaging in management of patients with bone and soft tissue sarcoma. *Cancer Biother Radiopharm.* 2001;16(1):37-46.
48. Franzius C, Daldrup-Link HE, Wagner-Bohn A, et al. FDG-PET for detection of recurrences from malignant primary bone tumors: comparison with conventional imaging. *Ann Oncol.* 2002;13(1):157-160.
49. Lucas JD, O'Doherty MJ, Wong JC, et al. Evaluation of fluorodeoxyglucose positron emission tomography in the management of soft-tissue sarcomas. *J Bone Joint Surg Br.* 1998;80(3):441-447.
50. Schwarzbach M, Willeke F, Dimitrakopoulou-Strauss A, et al. Functional imaging and detection of local recurrence in soft tissue sarcomas by positron emission tomography. *Anticancer Res.* 1999;19(2B):1343-1349.
51. Schwarzbach MH, Dimitrakopoulou-Strauss A, Willeke F, et al. Clinical value of [18-F]] fluorodeoxyglucose positron emission tomography imaging in soft tissue sarcomas. *Ann Surg.* 2000;231(3):380-386.
52. Iagaru A, Chawla S, Menendez L, Conti PS. 18F-FDG PET and PET/CT for detection of pulmonary metastases from musculoskeletal sarcomas. *Nucl Med Commun.* 2006;27(10):795-802.

53. Nakamoto Y, Cohade C, Tatsumi M, Hammoud D, Wahl RL. CT appearance of bone metastases detected with FDG PET as part of the same PET/CT examination. *Radiology.* 2005;237(2):627-634.
54. Taira AV, Herfkens RJ, Gambhir SS, Quon A. Detection of bone metastases: assessment of integrated FDG PET/CT imaging. *Radiology.* 2007;243(1):204-211.
55. Dalby K, Nielsen RG, Kruse-Andersen S, Fenger C, Durup J, Husby S. Gastroesophageal reflux disease and eosinophilic esophagitis in infants and children. A study of esophageal pH, multiple intraluminal impedance and endoscopic ultrasound. *Scand J Gastroenterol.* 2010;45(9):1029-1035.

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.