The study of musculoskeletal tumors greatly improved with the use of computed tomography (CT) and magnetic resonance imaging (MRI). These studies offer excellent imaging of a lesion’s anatomical extension and a clear identification of its active part after contrast administration. However, modern imaging is essentially morphologic; its low specificity only allows for etiological diagnosis in a few patients. Therefore, biopsy should remain the last step of staging for definite diagnosis and treatment planning for patients with musculoskeletal tumors.

**When to Perform a Biopsy**

The absolute indications for a musculoskeletal biopsy are primary or secondary tumors and infections. Biopsy is used to determine the nature of a solitary musculoskeletal lesion with non-specific imaging features, to confirm or exclude musculoskeletal metastasis in patients with a known primary malignant tumor, to confirm or exclude malignancy (most commonly metastases and myeloma) in patients with vertebral body compression fractures, to evaluate local recurrences after surgical or medical treatment, to examine the etiology of pathological fractures, and to identify musculoskeletal infections. Absolute contraindications for a musculoskeletal biopsy are coagulopathy and hydatidosis and instances when biopsy is not expected to give additional information or does not change patients’ management.

**How to Perform a Biopsy**

Biopsies should be performed if the diagnosis is uncertain or to confirm an imaging diagnosis before the introduction of treatment. Biopsy planning is different for elderly patients and children. In elderly patients, solitary bone lesions should be biopsied after imaging studies and staging are completed to differentiate between sarcomas and metastases. In children, imaging suggesting a sarcoma (most commonly osteosarcoma and Ewing’s sarcoma) or aggressive benign lesions (most commonly infections and eosinophilic granuloma) should be followed by a biopsy for histological confirmation before the beginning of treatment.

Biopsy can be open or closed. Open biopsy can be incisional or excisional. Closed or percutaneous biopsy can be performed using a fine needle and trocar or Tru-Cut (Cardinal Health, Dublin, Ohio) needle. Traditionally, open biopsy is the gold standard for musculoskeletal lesions because it provides an adequate tissue sample for histological diagnosis. However, because of the increased risks of infection, wound healing problems, hematoma formation, pathological fractures, and tumor contamination of healthy tissues, open biopsy should be performed only if a previously attempted percutaneous biopsy has been nondiagnostic. In addition, excisional biopsy should be performed only for superficial, small (3 cm or less) lesions that can be excised with clear margins. Moreover, in spinal and deep-seated pelvic lesions, an open biopsy can be a difficult procedure and has a significant risk of tumor spread and tissue contamination.

Closed biopsy techniques have gained popularity as less invasive procedures with similar diagnostic accuracy to open procedures. Percutaneous biopsy can be performed as an outpatient procedure because general anesthesia is rarely necessary. Regardless of the imaging guidance used, cost and time are lower than those of an open biopsy and exists less risk of tumor spread and infection. Computed tomography guidance is usually used for bone biopsies, whereas sonography guidance is used for soft tissue biopsies. In deep-seated spinal and pelvic lesions, CT-guided biopsy has increased accuracy and reduced complications. However, even in tertiary tumor centers, guided biopsy is associated with misdiagnosis, nonrepresentative tissue sampling, complications, and subsequent changes in treatment planning and prognosis. The most important risk of percutaneous biopsy is obtaining a small or insufficient tissue sample that...
may lead to underestimation of the tumor grade or uncorrected diagnosis. In addition, unavoidable violation by the biopsy needle of more than 1 compartment may increase the risk of tumor contamination of healthy tissues.\textsuperscript{1,3}

**Biopsy Procedure and Sampling**

A biopsy procedure should achieve harvesting of adequate tissue sample for histology and avoiding adjacent tissue contamination by not violating compartmental barriers, placing the biopsy tract within the planned surgical exposure, and performing an adequate approach to avoid hematoma formation. All biopsy procedures, regardless of the site and size of the lesion and the type of needles used, should be performed with strict adherence to anatomic compartments; uninvolved compartments should be avoided by the needle.\textsuperscript{6} For patients who have already undergone an operation, the needle approach should be performed on the surgical scar.\textsuperscript{3}

Complete staging with radiographs, bone scan, CT with contrast medium, and MRI should always be performed before the biopsy procedure for 2 reasons: the reactive changes determined by the biopsy may create difficulty in evaluation of the extension of the tumor and accurate imaging and staging can reveal a site of the disease that is more easy to approach.\textsuperscript{1,3} In children, general anesthesia is usually administered; in adolescents and adults, local anesthesia with local infiltration of 5 to 15 mL of 2\% solution of mepivacaine chloride are usually administered.\textsuperscript{3}

The CT slice thicknesses and intervals should be related to the location and size of the lesion. The authors use the following guidelines: 1-mm slice thicknesses and intervals for the cervical and upper thoracic spine; 1- to 2-mm slice thicknesses and intervals for the lower thoracic spine; and 1- to 2-mm slice thicknesses with 3-mm intervals for the lumbar and sacral spine. The authors use 1-mm slice thicknesses and intervals for the sternum, ribs, and clavicle and 1- to 2-mm slice thicknesses with 3-mm intervals for the remaining skeleton. Under CT guidance, the insertion point is selected and marked on the skin. Then, needle insertion with a coaxial or tandem technique is performed under sequential scans. A lower rate of milliamperage is used to monitor the needle approach to the lesion to reduce the radiation dose to the patient. The tissue sample harvested is sent to the pathologist in saline solution. A swab sample is obtained for microbiology if the diagnosis of musculoskeletal infection is suspected.\textsuperscript{3}

Multiple tissue samplings should be performed depending on the size, location, and suspected diagnosis of the lesion.\textsuperscript{3} The authors try to harvest at least 2 tissue samples at each biopsy procedure. More than 1 tissue sample should be obtained from spinal (Figure 2) and upper-extremity lesions, benign or low-grade malignant tumors, systemic malignancies (such as Hodgkin and non-Hodgkin lymphoma and myeloma), pseudotumors, inflammatory, sclerotic bone lesions (particularly if confined in bone), and small tumors (0.5 to 2.5 cm). Inadequate tissue sampling is less frequent in primary sarcomas, metastatic disease, mixed bone lesions with soft tissue mass, and medium or large (greater than 2.5 cm) lesions.\textsuperscript{3} In large lesions, due to their rapid growth, a higher possibility exists of targeting necrotic areas. In these cases, the authors review the prebiopsy imaging and target a viable tumor area to obtain a sample as homogeneous as possible. If a hypervascular lesion is suspected, an appropriate embolic agent should be available to control bleeding through direct biopsy needle application.\textsuperscript{3}

**Evolution of Biopsies**

Interventional musculoskeletal procedures have been performed since the 1970s under guidance. Currently, the significant evolution of imaging devices has further broadened the indications for imaging interventional musculoskeletal procedures. Novel imaging techniques have improved the feasibil-
ity of performing biopsies either with improved targeting of a lesion otherwise missed or with an increased rate of diagnosis. Positron emission tomography (PET) can provide an indication of the metabolic activity of a lesion; Positron emission tomography/CT fusion images can help to guide biopsy to the area of a viable lesion, resulting in a higher diagnostic rate, to evaluate the spread of metastatic disease, and to differentiate benign from malignant bone tumors (standard uptake values).\textsuperscript{4,5} Dynamic contrast enhanced MRI can also differentiate a benign from a malignant tumor regardless of the site and the type of tissue involved (cortical or medullary, bone or cartilaginous, or soft tissue). Magnetic resonance spectroscopy can characterize in vivo bone and soft tissue tumors, and diffusion weighted MRI can identify changes in the water diffusion and verify both the efficacy of a treatment or the occurrence of a recurrence and need for a new biopsy.

**CURRENT STATE OF BIOPSIES**

Imaging quality determines the success of guidance. In superficial lesions (not shielded by bone or soft tissue lesions), sonography-guided biopsy is currently considered the gold standard; compared with CT it has the advantage of real time imaging. In contrast, in deep-seated lesions (shielded by bone or implants soft tissue lesions), MRI presents an attractive tool for interventional radiology procedures. Even if it is not a real time imaging technique, it seems to have a higher diagnostic targeting accuracy than CT and sonography in selected indications; these include soft tissue lesions with increased edema and focal bone marrow abnormalities, such as tumors, inflammatory lesions, and infection.

A correct skin entry point is paramount for the success of any percutaneous procedure. Four targeting methods can be used: (1) external references (framed stereotaxy), (2) internal references (based on previous 3-dimensional acquisition or data), (3) MRI tracking software (provided either by the scanner manufacturer or by an external vendor), and (4) a self-reference method (based on anatomical landmarks, grid, or fat/liquid containing capsule). It is mandatory to acquire images at least of 2 perpendicular planes for identifying the target anatomy.

The MRI sequences used for interventional purposes are different from those used for diagnostic imaging; it is important to reduce the scan time without losing the image contrast and spatial image resolution. Spectral presaturation inversion recovery, Short TI inversion recovery, and gradient echo sequences are used; however, they produce increased implant-related artifacts compared with spin echo sequences. Implants generate artifacts due to signal void. Respiratory movements can affect the procedure; therefore, anesthesia or sedation are necessary, particularly for procedures in the thoracic spine.

**CONCLUSION**

Complete staging is necessary prior to CT-guided percutaneous biopsy for musculoskeletal lesions. The diagnostic accuracy of the procedure is related to the diameter of the biopsy needle or trocar; the site, size, and histology of the lesions; and the number of tissue samples obtained. In the spine, particularly the cervical spine and with small size lesions, the rate of accurate diagnosis is low. Repeat CT-guided biopsy should be performed for nondiagnostic initial procedures. Only in a few cases is an incisional biopsy necessary.

**REFERENCES**