Percutaneous Minimally Invasive Thermal Ablation of Musculoskeletal Lesions

Usefulness of PET-Computed Tomography

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KEYWORDS

• PET-CT • FDG • PET-MR • Musculoskeletal metastases • Thermal ablation • Local tumor control • Pain palliation

KEY POINTS

- Bone is the third most common site of metastatic disease and percutaneous minimally invasive thermal ablation is becoming an important contributor to multidisciplinary treatment algorithms.
- PET-computed tomography scan has an integral role in preablation imaging and postablation follow-up in the musculoskeletal system, especially in the setting of local tumor control.
- Nuclear medicine physicians and radiologists interpreting postablation PET-computed tomography studies must be familiar with expected postablation findings as well as indicators of tumor recurrence/progression.

INTRODUCTION

Bone is the third most common site of metastatic disease; up to 85% of patients with breast, prostate, kidney, and lung cancers are found to have osseous metastases at autopsy.[1] Symptomatic patients most commonly present with pain, which is multifactorial owing to tumor-induced biochemical stimulation of periosteal and endosteal nociceptors, tumor mass effect on surrounding vital structures particularly nerves or spinal cord, or associated pathologic fracture.[1,2] In patients with painful osseous metastases, the goal of therapy is to achieve rapid and durable pain relief.[3] Radiation therapy is the standard of care for pain palliation secondary to metastases, but it has important limitations. First, certain tumor histologies respond variably to radiation therapy, particularly renal cell carcinoma, melanoma, and soft tissue sarcoma.[4–6] Second, radiation therapy may be limited by the cumulative radiation tolerance of nearby radiosensitive organs, such as the spinal cord or bowel. Third, some patients may not respond until 4 to 6 weeks after radiation therapy, which is suboptimal for patients with short life expectancies.[7] Finally, radiation therapy may exclude patients from certain clinical trials. Additionally, painful bone metastases are often refractory to systemic therapies such as chemotherapy, hormonal therapy, radiopharmaceuticals, and bisphosphonates.[8] Surgical intervention, including resection, cementation and internal fixation, and stabilization,

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is often of limited benefit in patients with osseous metastases because of its morbidity, patients' often poor functional status, and the short expected life span. These procedures are generally reserved for patients with neurologic compromise or osseous instability. Pain palliation with systemic analgesics remains the only alternative for many patients.[9]

Over the past few years, there has been growth in the use of minimally invasive percutaneous thermal ablation technologies for management of osseous metastases including radiofrequency ablation, cryoablation, microwave ablation, and high-intensity focused ultrasound treatment, which may be performed in an outpatient setting under conscious sedation.[10–19] There is typically rapid recovery and no hindrance or compromise of adjuvant radiation or chemotherapy. Percutaneous thermal ablation for osseous metastases is performed to achieve pain palliation, local tumor control, or both (often with cementation for pathologic fracture stabilization or prevention). In cases of osseous oligometastatic disease (<5 lesions), ablation may be performed with curative intent.[14,16]

PET-computed tomography (CT) scanning provides both anatomic and metabolic information and has an integral role in the minimally invasive percutaneous ablation of bone metastases. This article discusses the role of PET-CT scanning in percutaneous minimally invasive ablation of osseous metastases including diagnosis and preprocedural factors related to patient selection and procedure planning, intraprocedural imaging guidance, and posttreatment imaging assessment.

PREPROCEDURAL PET-COMPUTED TOMOGRAPHY SCANS

PET-CT scanning, along with MRI and routine CT scans, plays an important role in the initial diagnosis and staging of primary bone tumors and osseous metastases. In clinical practice, [18F]-fluoro-2-deoxy-D-glucose (FDG) is the most commonly used radiopharmaceutical for the PET-CT evaluation of osseous metastases. The expanding list of PET radiopharmaceuticals with the potential to target specific tumor types or specific biological characteristics of the tumors supports growing applications of PET-CT scanning and PET-MRI for preablation assessment of musculoskeletal lesions[20–22] (**Fig. 1**). Such radiopharmaceuticals include 18F- or 11C-acetate, 18F- or 11C-choline, and 18F-sodium fluoride.[20–22] The major advantages of PET-CT scans and PET-MRI include the ability to detect tumors that are occult on conventional anatomic cross-sectional imaging and to identify metabolically active portions of tumors. This factor is particularly useful for the detection of tumor recurrence after ablation or other therapies to plan subsequent percutaneous ablation.[23]

Preablation PET-CT scanning provides information for preprocedural planning to support accurate placement of ablation probes, electrodes, or antennae to safely achieve the therapeutic goal. When treating with palliative intent, ablation of all bone–tumor and soft tissue–tumor interfaces is sufficient. However, to achieve local tumor control, the ablation zone must completely envelope the gross tumor volume plus an ablative margin of at least 5 mm.[24] In addition, preprocedural PET-CT scanning is important for the choice of ablation technology. For example, cryoablation is favored for osteoblastic lesions or larger bone tumors with soft tissue components and complex geometries, because multiple cryoprobes can be strategically arranged to produce a contiguous ice ball with a tailored configuration.[12,16] Radiofrequency ablation is favored for vertebral body osteolytic or mixed lesions as well as challenging-to-reach anatomic locations, such as the posterior vertebral body, where navigating tip of recently introduced electrodes can be articulated in different orientations through the same osseous access site.[25] Microwave ablation is most commonly used for musculoskeletal lesions where the surrounding vital structures are reasonably distant from the planned ablation zone.[25] Furthermore, when the planned ablation zone is in close proximity to structures at risk for ablation-induced injury, such as the spinal cord, spinal nerve roots, peripheral nerves, skin, and vital torso soft tissues including the bowel, precise assessment of the surrounding structures on preablation PET-CT scans helps the operator to develop appropriate passive and active thermal protection strategies to prevent undesired thermal injuries.

INTRAPROCEDURAL PET-COMPUTED TOMOGRAPHY SCANS

Investigators have successfully used PET-CT scans for percutaneous interventions, including needle biopsies and thermal ablations.[26–28] A variety of techniques have been described to incorporate PET imaging into intraprocedural guidance, including the fusion of PET images obtained at the beginning of the procedure with CT images obtained intermittently during the procedure, fusion of intraprocedural CT images with preablation PET, and direct use of PET images for needle guidance.[26–28] Fusion of CT and PET