Clinical PET-MR Imaging in Breast Cancer and Lung Cancer

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KEYWORDS

• PET-MR imaging • Hybrid imaging • Breast cancer • Lung cancer • Oncology • Thoracic imaging

KEY POINTS

- PET-MR imaging may potentially detect more distant metastases in breast cancer compared with PET-CT or MR imaging alone, and it has the potential to guide breast biopsies based on higher specificity compared with MR imaging.
- PET-MR imaging has the potential to detect distant metastases of lung cancer with even higher sensitivity than PET-CT or MR imaging alone.
- Current PET-MR imaging systems will not replace chest computed tomography (CT) for detection of small primary lung tumors.
- PET-MR imaging offers advantages compared with PET-CT with respect to molecular-anatomic lesion registration, motion correction, radiation dose, and patient convenience.
- PET-MR imaging has the potential to allow precise quantification of molecular information obtained by both PET and MR imaging, and allows for voxelwise correlation and temporally aligned data that may inform patient management in the future.

INTRODUCTION

Advances in radiographic computed tomography (CT), MR imaging, PET, and combined PET-CT have dramatically improved the management of patients with cancer over the past 2 decades. For years, researchers and clinicians have wondered if combining PET with MR imaging would offer similar or even greater advantages compared with PET-CT.

Recent advancements in MR imaging scanners and the advent of MR imaging-compatible solid-state PET detectors that replace traditional photomultiplier tubes have made it possible to finally combine MR imaging and PET into a single device that acquires whole-body PET-MR images. Potential advantages of hybrid PET-MR imaging compared with PET-CT include superior identification of lesions in the brain, breast, liver, kidney, and bones, as well as enhanced evaluation of the margins of lesions. Improved anatomic registration with PET secondary to simultaneous image acquisition is now a reality with the advent of simultaneous PET-MR imaging scanners. Furthermore, the application of multiparametric quantitative imaging in MR imaging and functional PET has the potential to better guide patient management and to decrease the number of imaging studies required for clinical decision-making, resulting in less radiation exposure and improved patient satisfaction (**Box 1**).

Neoplasms of the thorax, including those of the breast and lung, are some of the most commonly

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Box 1
Typical breast cancer or lung cancer PET-MR imaging protocol

- 15 mCi ^{18}F- 2-fluoro-2-deoxy-D-glucose (FDG) intravenously, wait 60 minutes, void
  - Can perform diagnostic breast MR imaging during radiotracer uptake period if desired (for patients with breast cancer)
- Scan from skull vertex to thighs
- Multichannel head and neck coil, flexible body coil
- 6 minutes per bed PET acquisition with simultaneous MR imaging sequences
  - Dixon MR imaging attenuation correction images
  - 3-dimensional T1-weighted images
  - 3 b-value diffusion-weighted imaging (DWI)
  - Axial T2-weighted half-Fourier single-shot turbo spin echo (HASTE) or short tau inversion recovery (STIR) images if desired by imaging physician
- Inject gadolinium-based contrast material intravenously
  - Postcontrast 3-dimensional T1-weighted images of liver and brain

diagnosed cancers in the western world, which cause exceptionally high morbidity and mortality and are areas of active study in the emerging field of clinical PET-MR imaging. According to cancer statistics in 2015, approximately 234,190 people were diagnosed with breast cancer and 221,200 were diagnosed with lung neoplasms in the United States; this includes an estimated 40,730 and 158,040 related deaths secondary to these 2 diseases, respectively.[1] Overall survival is greatly influenced by the stage of the neoplasm at the time of diagnosis and by the histologic subtype of cancer.

PET systems have greatly improved in the last few decades with faster imaging time and improved scanner resolution; the combination of CT with hybrid PET-CT scanners has merged anatomic and molecular imaging, allowing for more accurate diagnosis and staging of many neoplasms. ^{18}F- 2-fluoro-2-deoxy-D-glucose (FDG) is a radioactive analogue of glucose and the most commonly used PET radiotracer in clinical practice. The clinical implementation of multiple novel clinical PET radiotracers, along with ongoing research of various others, has advanced and improved the potential molecular imaging capabilities of PET, accurately permitting in vivo imaging of various important clinical markers, including cell surface receptor expression, DNA production or repair, and hypoxia.[2,3] MR imaging has also evolved with new and faster sequences that allow for whole-body imaging, as well as functional imaging sequences, including magnetic resonance spectroscopy (MRS), perfusion imaging, and diffusion-weighted imaging (DWI), which have expanded the use of MR imaging in characterizing disease. With all of the added benefits of combined PET-MR imaging, the imaging algorithm currently used for thoracic cancers can be further optimized, potentially allowing for superior clinical information to be obtained from a single scan (**Box 2**).

PET-COMPUTED TOMOGRAPHY IN BREAST CANCER

Breast cancer remains exceedingly prevalent in the Western world and is a leading cause of mortality in women. Once diagnosed, survival is inversely related to the extent of disease at diagnosis, currently characterized with the tumor-node-metastasis (TNM) staging system. Metastases to axillary lymph nodes have a profound influence on patient prognosis, with

Box 2
PET-MR imaging pitfalls in breast and lung cancers

- Metallic artifacts in breast tissue expanders can generate signal dropout on attenuation maps and result in underestimation of standardized uptake value (SUV) in chest wall lesions.
- Misclassification of lung tissue as air can underestimate SUV in lung lesions.
- Misclassification of hilar lymph nodes as air can result in SUV underestimation.
- Clinical PET-MR imaging readers should keep in mind the breath-hold protocol for various sequences obtained during PET-MR imaging and understand the potential for lesion misregistration relative to PET.
- MR imaging motion-tracking holds great promise for motion correction of PET datasets in the near future, without additional radiation exposure.
- Geometric distortion on DWI datasets results in misregistration to PET data; this should be kept in mind during clinical interpretation.