The Emerging Role of PET/MR Imaging in Gynecologic Cancers

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KEYWORDS

• PET/MR imaging • Gynecologic malignancies • Uterine cervical cancer
• Uterine endometrial cancer • Ovarian epithelial cancer

KEY POINTS

- PET with 2-deoxy-2-[^{18}F]-fluoro-D-glucose (FDG) has a role in staging gynecologic malignancies.
- Current data show that PET/computed tomography (CT) and PET/MR imaging have similar diagnostic performance for detection of malignant lesions with the advantage of significant reductions in radiation exposure by removing the CT component of PET/CT, which is especially important in this population undergoing serial examinations.
- FDG-PET/MR imaging may improve the diagnostic accuracy for local and distant metastatic disease because of the superior soft tissue contrast of MR imaging compared with CT.
- Functional MR techniques and multiparametric imaging applications such as diffusion-weighted imaging and dynamic contrast-enhanced imaging improve the characterization of lesions and provide quantitative biomarkers for assessment of response to treatment.
- Patients with gynecologic malignancies who require both PET and MR imaging should undergo a simultaneous PET/MR imaging examination that combines metabolic, anatomic, and functional imaging and decreases misregistration caused by patient motion or physiologic changes/motion of various organs.

INTRODUCTION

This article summarizes the current literature on PET/MR imaging in gynecologic malignancies and outlines the emerging clinical value of PET/MR imaging as an imaging tool in the management of the 3 most common gynecologic cancers: uterine cervical, uterine endometrial, and ovarian epithelial. Our experience with simultaneous PET/MR imaging is used to show the advantages and challenges of this new hybrid imaging modality in patients with gynecologic cancers.

In the last decades, the standard of care for the initial staging and the subsequent assessment of treatment response for many cancers has become PET in conjunction with computed tomography (CT) using the glucose analogue 2-deoxy-2-[^{18}F]-fluoro-D-glucose (FDG).[1–3] Despite its central role, FDG-PET/CT has well-recognized limitations with respect to local tumor staging and the characterization of certain lesions in patients with gynecologic cancer.[4] In these cases, because imaging is central to staging as well as determining

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prognosis and treatment strategy, further evaluation with MR imaging can be performed to ensure proper clinical management. The role of MR imaging is well established in gynecologic cancers, because it complements the molecular and metabolic data of PET with its superior soft tissue contrast and anatomic resolution, lack of ionizing radiation, and the ability to assess cellular density by MR based diffusion weighted imaging (DWI) and tissue perfusion and oxygenation by dynamic contrast-enhanced (DCE) MR imaging.[5–7] Accordingly, PET/MR imaging has significant potential to positively affect patient care by improving the diagnosis, initial staging, and subsequent management decisions in patients with gynecologic cancers.

Over the last few years, the increased number of PET/MR imaging installations in clinical settings and the growing evidence with respect to its utility have provided a deeper understanding of the benefits of the routine clinical use of PET/MR imaging to justify the added expense and complexity compared with PET/CT. This article summarizes the current body of evidence on gynecologic cancers, and delineates the limitations of these two hybrid imaging modalities as related to current challenges and areas likely to benefit from the clinical use of PET/MR imaging. It presents case examples to show the specific advantages of simultaneous PET/MR imaging based on our experience with gynecologic cancers in a clinical setting.

PET/MR IMAGING TECHNICAL BACKGROUND

In order to better understand the inherent advantages, disadvantages, and limitations of PET/MR imaging, this article briefly discusses their design and development. At present, PET/MR imaging systems can acquire MR and PET data either simultaneously or sequentially. Integrated PET/MR imaging systems simultaneously acquire PET and MR imaging data allowing concurrent imaging of the same region within a single gantry housing both the MR imaging and PET scanners. In the sequential PET/MR imaging acquisition, spatially separate individual PET and MR imaging scanners are connected by a common moving table that functions to reduce changes in patient positioning between imaging examinations. The installed base of PET/MR imaging systems currently comprises approximately 80% simultaneous acquisition units, driven by the multimodality multiparametric imaging capabilities in both the spatial and temporal domains of this hybrid modality.[8]

At present, the most critical limitation of both sequential and simultaneous PET/MR imaging examinations is the accuracy of the MR imaging–derived attenuation correction (MR-AC) algorithms for PET. In PET/CT, the CT-derived attenuation correction is directly generated from the electron density information yielding photon-corrected PET images. Unlike CT, the MR imaging signal acquired during PET/MR imaging instead correlates with proton density and tissue relaxation properties and does not reflect electron density. Thus, alternate attenuation correction methods were developed for PET/MR imaging. The current approaches to MR-AC can be classified into 3 categories: segmentation, atlas, and emissions-based methods.[9–12] In the clinical whole-body imaging setting, MR-AC is typically derived from a segmentation-based method using Dixon sequences followed by image segmentation that classifies voxels into 4 classes of tissues (eg, background/air, soft tissue, fat, lung), creating an attenuation map. This approach uses the patient's imaging data and thus is reasonably accurate to account for anatomic and physiologic variants. Although there have been steady improvements in segmentation-based MR-AC methodologies, many technical problems remain. Correct delineation of the lung parenchyma may occasionally fail; Dixon classifications may generate incorrect voxel tissue values; and patient motion, both physiologic and nonphysiologic, all can result in artifacts that propagate into the MR-AC PET images and thus affect clinical image interpretation.[13] In addition, current segmentation-based MR attenuation maps are derived without cortical bone being included because cortical bone does not provide adequate MR imaging signal to be represented in MR-AC maps. Thus, the standard Dixon method does not account for cortical bone, resulting in local underestimation of standardized uptake values (SUVs) for tissues adjacent to or within cortical bone compared with PET/CT.[14] Although these limitations exist, the current MR-AC methods are likely sufficient for clinical use (ie, when highly precise SUV measurements are not necessary to diagnose and follow treatment response for most lesions).

PET/MR IMAGING PROTOCOL AND WORKFLOW DESIGN

At the authors' institution, PET/MR imaging examinations are performed on a simultaneous 3T PET/MR imaging system (Siemens Biograph mMR; Siemens Health Care, Erlangen, Germany). The whole-body PET/MR imaging protocol is complemented by dedicated pelvis sequences in patients with gynecologic cancers. The MR imaging provides different image contrasts through