Cardiac Applications of PET/MR Imaging

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KEYWORDS

• PET/MR imaging • Cardiology • Attenuation correction • Myocardial ischemia • Cardiomyopathy

KEY POINTS

- Early efforts of cardiovascular PET/MR imaging research emphasized accurate magnetic resonance (MR)-based attenuation correction of PET data.
- PET/MR imaging in cardiology shows promise in infarct characterization, ischemia, and atherosclerosis evaluation.
- Utility of PET/MR in other cardiovascular conditions, such as cardiac sarcoidosis and myocarditis, also shows promise.

INTRODUCTION

Simultaneous acquisition PET/MR imaging combines the anatomic capabilities of cardiac MR imaging with quantitative capabilities of both PET and MR imaging. Cardiac PET/MR imaging has the potential to provide thorough assessment of myocardial ischemia, infarction (**Fig. 1**), and function as well as characterization of cardiomyopathies such as cardiac sarcoid and myocarditis. In this article, the authors discuss the technical challenges specific to cardiovascular PET/MR imaging followed by a discussion of the use PET/magnetic resonance (MR) in various cardiovascular conditions.

Although much of the early PET/MR imaging research centered on oncology and neurology applications, the number of research publications on PET/MR imaging cardiovascular applications has increased over the last few years.[1,2] Simultaneous acquisition cardiac PET/MR imaging combines the reference standard for myocardial perfusion (PET) with the reference standard for functional assessment (gated cine MR imaging). In addition, cardiac PET/MR has the ability to assess viability both by ^{18}F-fluorodeoxyglucose (^{18}F-FDG) PET and by MR imaging, specifically assessing regions of myocardial infarction and fibrosis by late gadolinium enhancement (LGE) or T1 mapping.[3] Myocardial edema can be evaluated by T2 MR imaging, and molecular information on inflammation and macrophage presence can be targeted by novel PET tracers.[2,4]

Limitations to routine clinical use of cardiac PET/MR imaging have included validation of MR imaging for PET attenuation correction and methods to motion correct both PET and MR imaging. Although multiple articles have been now been published validating MR imaging for attenuation correction in cardiac imaging,[5–7] and methods exist to fuse diastolic-acquired list-mode data to diastolic MR imaging data, PET optimal respiratory and cardiac motion correction methods are still in the process of being explored.

Box 1 lists some of the advantages and limitations of PET/MR as it pertains to cardiovascular imaging.

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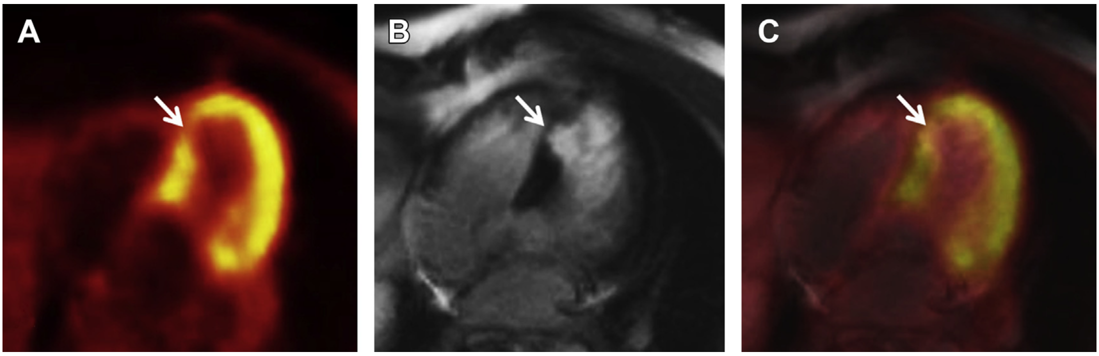

Fig. 1. Cardiac PET-MR imaging in a 65-year-old man with a septal wall myocardial infarction. (*A*) ^{18}F-FDG PET 4-chamber long-axis PET reconstruction shows focal region of decreased radiotracer uptake (*arrow*) that colocalizes to the area of scar shown by (*B*) increased contrast enhancement (*arrow*) on a T1-weighted segmented gradient recalled echo late gadolinium-enhanced (LGE) MR image. (*C*) Fused 18F-FDG PET and LGE MR images.

TECHNICAL CHALLENGES OF PET/MR CARDIOVASCULAR IMAGING

The technical challenges of cardiac PET/MR imaging are unique.

1. In terms of *attenuation correction*: there are few bony structures in the immediate vicinity of the heart, making accurate MR-attenuation correction easier to achieve in comparison neurologic imaging.
2. In terms of *motion correction*: 2 types of motions, including respiratory and cardiac motions, need to be tracked and motion-corrected for optimal image registration.
3. Specific to cardiac PET imaging, *optimizing myocardial radiotracer uptake* is necessary especially if ^{18}F-FDG will be used, and patient preparation protocols are needed to either enhance or suppress myocardial glucose uptake, depending on the clinical question.

Attenuation Correction

Imaging a variety of organ systems requires different sets of MR sequences and PET radiotracers to generate the maximal complementary information between anatomy, function, and specific molecular signals. Accurate quantitation of radiopharmaceutical uptake is highly dependent on accurate attenuation correction of the PET signals, in the absence of a conventional computed tomographic (CT)-based μ-map.

Box 1
Potential advantages and limitations of PET/MR over PET/computed tomography in cardiovascular imaging

Potential advantages of PET/MR over PET/CT in cardiovascular imaging:

- Reduced radiation dose in comparison to PET/CT
- Combined metabolic, functional, and high-contrast anatomic imaging
- Viability assessment by both metabolic and anatomic methods
- Combined PET and MR imaging examination is shorter than separately performed examinations
- Potential for myocardial blood flow comparison by both MR imaging and PET stress perfusion

Potential limitations of PET/MR in cardiovascular imaging:

- Smaller inner bore of the PET/MR imaging scanner may exclude oversized patients
- No breath-hold during PET acquisition means that alternate MR imaging methods of respiratory motion suppression are necessary
- Technical challenges with dual respiratory and cardiac motion correction
- Contraindications to MR imaging (such as implantable defibrillators or MR–non-compatible pacemakers)
- Non-MR imaging–compatible generators (Rubidium-92) are a challenge