Hybrid PET/MRI imaging of the heart: feasibility and initial results

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Target audience

The presentation is mainly addressed to physicians and physicists interested cardiac molecular imaging.

Purpose

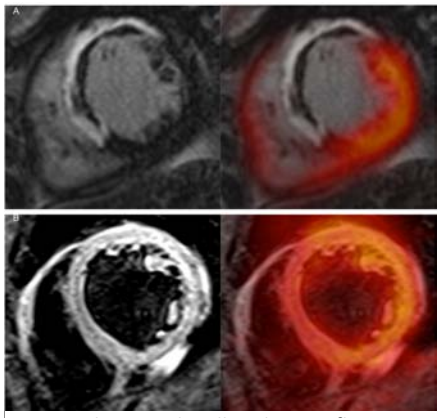
The purpose of this study was to evaluate the potential as well as the challenges of hybrid imaging of the heart with an integrated PET/MRI system capable of simultaneous data acquisition (PET/CMR) and to discuss its potential clinical impact.

Methods

Fifteen consecutive patients with myocardial infarction (MI; n=10) or suspected myocarditis (n=5) underwent PET/CMR with ^{18}F-FDG on an integrated 3T MR-PET system (Biograph mMR, Siemens). Ten patients underwent additional PET/CT before PET/CMR. The MRI protocol comprised the following sequences: 1) axial 2D HASTE of the thorax, 2) SSFP cine imaging, 3) 2D TIRM sequence for imaging of myocardial edema, 4) segmented 2D inversion recovery Turbo-FLASH sequences 10 min after gadolinium injection for late gadolinium enhancement imaging (LGE). Cine, TIRM and LGE sequences were ECG-triggered and acquired in breath-hold in three long axes views (4CV, 3CV, 2CV) and in contiguous short axes views covering the entire left ventricle (LV). Dedicated phased-array mMR body surface coils were used. PET attenuation correction maps were calculated from fat-only and water-only Dixon-based sequences by segmentation into background, lung, fat and soft tissue. According to the to the 17-segment model, tracer uptake (PET; 0: normal, 1: reduced), wall motion (cine; 0: normal, 1: abnormal) and late enhancement (LGE; 0: no enhancement, 1: enhancement) were visually assessed for each segment by two readers in consensus. The maximum standardized uptake value (SUV_{max}) was measured in corresponding myocardial locations in MR-PET and PET/CT, respectively. The contrast ratio (CR) between non-/infarcted myocardium in LGE was assessed as $CR_{inf-noninf} = (SI_{inf} - SI_{noninf})/(SI_{inf} + SI_{noninf})$ and compared to CRs from 10 consecutive CMR examinations on a 1.5T scanner (Magnetom Aera, Siemens). Infarction sizes were measured (% entire LV myocardium) on LGE and PET images. Agreement between PET, cine and LGE data was calculated using Cohen's kappa (κ). Agreement between MR-PET and PET/CT was estimated with coefficients of variation (CV) and Bland-Altman plots. Significance testing was performed using t-tests.

Results

Agreement between PET and LGE over all patients and segments was κ=0.81 (p<0.001), between PET and cine it was κ=0.79 (p<0.001). Fifty-two of 170 segments (31%) were rated as infarcted in PET compared to 47 (28%) in LGE and 40 (24%) in cine. Infarction sizes were 20±17% in PET and 19±19% in LGE images (p=0.65) with limits of agreement of -13% and 11%. $CR_{inf-noninf}$ was 0.87±0.28 on the 3T MR-PET and 0.81±0.29 on the 1.5-T scanner (p=0.14). Myocardial SUV_{max} was 6.51±3.42 in PET acquisitions on the MR-PET and 6.82±3.16 on the PET/CT (paired t-Test: p=0.21) with limits of agreement of -3.04 and 3.65. The CV was 0.18. In 9 of 10 patients with MI LGE, Cine and PET data were in good concordance (expl. figure A). In one patient with MI, no enhancement was found in LGE, whereas PET showed a reduced tracer uptake, that matched myocardial edema (TIRM). In one patient with suspected eosinophilic myocarditis PET/CMR revealed a septal hypokinesia and an inflammation of the mediastinal and pulmonary vessels. In one patient with suspected myocarditis a patchy pattern of LGE was found in the posterior wall with corresponding edema and increased tracer uptake (Figure B). In all remaining cases myocardial inflammation was ruled out.



A: MI in the septal wall with no-reflow zone and no tracer uptake (left: LGE, right: LGE+PET).
B: Myocarditis with edema and increased tracer uptake in the lateral wall (left: TIRM, right: TIRM+PET)

Discussion

With superior insights into cardiac morphology and function MRI has been well established in cardiac imaging. Integrated with PET into one device it is now extended by a metabolic perspective. While such an integrated solution has been hypothesized before[1], the present study is the first to demonstrate its feasibility on a commercially available integrated MR-PET scanner.

Conclusion

Integrated cardiac MR-PET with ^{18}F-FDG is feasible, offers a complementary view on myocardial disease and could advance to become the diagnostic tool of choice.

References

1. Nekolla SG, Martinez-Moeller A, Saraste A. PET and MRI in cardiac imaging: from validation studies to integrated applications. Eur J Nucl Med Mol Imaging. 2009;36 Suppl 1:S121-30