PET-MRI in Cardiac Imaging: Initial Experience

Mallinckrodt Institute of Radiology
Washington University School of Medicine

Pamela K. Woodard, M.D.
Professor of Radiology and Biomedical Engineering
Head, Advanced Cardiac Imaging (MR/CT)
Director, Center for Clinical Imaging Research
Disclosure

• Washington University has a Biograph mMR System and a Research Agreement with Siemens.
Center for Clinical Imaging Research
Washington University in St. Louis

1.5 T
1.5 T
3.0 T

DS CT
PET/CT
Biograph mMR Promotes Harmony

Glenn Foster
MR Tech

Linda Becker
Nuc Med Tech
Cardiovascular PET-MR Team

- Robert Gropler, M.D.
- Barry Siegel, M.D.
- Richard Laforest, Ph.D.
- Luciano Amado, M.D.
- Jie Zheng, Ph.D.
- Agus Priatna, Ph.D.
- Yongjian Liu, Ph.D.
- Suzanne Lapi, Ph.D.
- Monica Shokeen, Ph.D.
- Jeff Lau, M.D.
- Shivak Sharma, M.D.
- Xingyu Nie, Ph.D.
- Sally Schwarz, M.S., BCNP
- Bob Mach, Ph.D.

- Jennifer Frye, RT
- Glenn Foster, RT
- Linda Becker, RT
- Mike Harrod, RT
- Tim Street, RT
- Debi Delano, RT
- Donna Lesniak, RN
- Molly Mohrman, RRT
Simultaneous PET-MRI

- 3T Verio Siemens Whole Body MR System (60 cm bore)
- PET System – APD (instead of PMT)
New Technology: Simultaneous PET/MR

- 3T Verio Siemens Whole Body MR System
- PET System – APD (instead of PMT)
Cardiac PET-MR: Black Box
How to acquire simultaneously gated cardiac PET and MR images?

Patients: Patients injected with 18F-FDG for oncologic PET imaging with cardiac uptake.

- Scout Imaging
- 2-PT DIXON AC
- 7-10 MIN DELAY
- SINGLE SHOT T1-WEIGHTED IR TRUEFISP DCE LV BASE TO APEX (acquired in DIASTOLE)
- 15-20 min PET ACQUISITION in LIST MODE
- PET DATA BINNED and RECONSTRUCTED INTO 8 PHASES – DIASTOLIC PET
- DATA FUSED WITH MR IMAGES ACQUIRED IN DIASTOLE

Patients: Patients injected with 18F-FDG for oncologic PET imaging with cardiac uptake.
Simultaneous acquisition of EKG-gated PET and delayed contrast enhanced (DCE) cardiac MR images (simultaneous acquisition of MR 2-point Dixon also acquired for AC prior to contrast injection). PET data acquired in list mode and binned. **DCE MR Images acquired in diastole are fused with diastolic PET data to create the center image.** Patient has a normal heart.

Woodard, Laforest, et al.
Caveats

• AC free-breathing

• ALL IMAGING (MR AND PET) ACQUIRED FREE-BREATHING

• For PET, can’t EKG-gate and RESPIRATORY gate at the same time!

• FIXED ISO-CENTER (During simultaneous CMR scanning, table position can’t move)

• Post-processing off-line: no good program for combined cardiac PET-MR viewing/analysis
PET data acquired in list mode, binned into 8 phases to create PET cine.
18F-FDG Cardiac PET-MR Viability Cine

PET data acquired in list mode, binned into 8 phases to create PET cine. Fused with simultaneously acquired free-breathing real time SSFP cardiac cine.

Laforest, Woodard, et al.
Clinical Projects in Progress: Simultaneous Perfusion Acquisition

- Simultaneous $^{13}$N-ammonia PET-MR Myocardial Perfusion using Regadenoson: Clinical Protocol Development (Funded by Astellas)

- **PET perspective:** MR component reduces radiation dose and shortens exam time (DCE infarct imaging can replace rest $^{13}$N-ammonia PET imaging).
- **MR perspective:** PET component may improve accuracy (better coverage).
• What are the benefits of simultaneous PET and MRI myocardial perfusion?
Limitations of Dynamic Cardiac MR First-Pass Perfusion:
Number of Slices Limited by Length of R-R Interval

- Advantage – relatively high spatial resolution.
Contrast-Enhanced MRI of the Heart: How it works

- Normal Myocardium
- Infarcted Myocardium
- Ischemic Myocardium

Contrast injection

Dynamic First-Pass Perfusion PET and MR (Pharmacologic Stress): Both infarcted and ischemic myocardium hypoperfused.

Delayed Enhancement Viability: Infarcted myocardium BRIGHT

< 1 min

> 5 min

time
A 71-year-old patient with increasing symptoms of angina pectoris. Rest perfusion images (bottom) show decreased $^{13}$N-ammonia uptake in the inferior and apical myocardium, indicating a scar of mild extent. Stress images (top) demonstrate a further decrease of $^{13}$N-ammonia uptake at pharmacological stress in the inferior and apical myocardium, indicating severe ischemia.

Electrophysiology Direction

- PET-MR Characterization of Myocardial Infarction Heterogeneity as a Marker of Inducible Monomorphic Ventricular Tachycardia
  - PET myocardial SUV maps/metabolic function, MOLLI T1 maps, DCE combination may be a better predictor of arrhythmia susceptibility than MR alone.
Delayed-contrast MRI image

Anatomical Scar

Electro-physiological Substrate

CT-MRI Registration

Yong, Woodard, Rudy; Washington University, St. Louis
Abnormal EP Substrate - Post-Myocardial Infarction

ECGI reconstructed epicardial electrograms

Scar is shown in red.
Moving Forward

• AC with respiratory gating/EKG-gating (?)
• Methods of suppressing respiratory motion in MR
  - Single shot
  - Multiple averages
  - Real-time
• Simultaneous PET-MR respiratory gating
• PET-MR motion correction
• Viewing/analysis software