Initial experience: combination of MR pharmacokinetic modeling and FDG uptake using simultaneous dynamic contrast enhanced MRI and PET imaging

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Target Audience: Physicists and radiologists interested in quantitative breast oncologic imaging using a simultaneous PET/MR platform.

Purpose: Dynamic contrast enhanced (DCE)-MRI and FDG-PET are highly sensitive methods for detecting breast cancer, but they both lack specificity. The combination of these two modalities has been shown to be a promising approach [1, 2]. MR pharmacokinetic modeling has been shown to correlate with prognostic factors and breast cancer subtypes [3], but the combination of these variables with simultaneously acquired metabolic activity has not been assessed. Thus, the objective of this study was to investigate the feasibility of improving lesion characterization with a combination of MR pharmacokinetic and FDG uptake data using simultaneous PET/MR acquisition.

Methods: Simultaneous MR and PET scans were performed for eight women (ages 29-60, mean 49) with known breast cancers. Seven cancers were invasive ductal carcinomas (IDC) and one malignancy was an invasive lobular carcinoma (ILC), as proven by surgical excision. A whole-body integrated 3 T PET/MR scanner (Biograph mMR, Siemens Healthcare, Erlangen, Germany) was used to simultaneously acquire MRI and PET images of the breast in the prone position with a 4-channel breast coil (Noras MRI Products). The PET/MR was performed 90-120 minutes after a single FDG injection (~15mCi) for a routine PET/CT. During the MR scan, PET events were simultaneously accumulated for 15 minutes and images were reconstructed on the vendor platform incorporating T1-Dixon-based μ-maps accounting for both patient and hardware, including the breast coil. Mean and maximum SUV values were measured for each lesion in the axial plane using a vendor software module (MIM Software Inc.). DCE-MRI data was acquired with a prototype radial 3D gradient echo sequence (radial VIBE [4]) with TR/TE = 3.6/1.7 ms, FA = 10 deg, FOV 280 mm, 1.1 x 1.1 x 2.0 mm voxel, 256 x 256 x 128 image matrix, 420 radial views/frame, 2 min/frame, and 4 frames in total. Injection of contrast agent, Gd-DTPA (Magnevist, Bayer), was administered immediately after the first frame. High temporal resolution images (5 s/frame) were reconstructed off-line using Golden-angle RAdial Sparse Parallel (GRASP) MRI [5]. T1 maps were generated using different flip angles. DCE kinetic model analysis of the regions of interest (ROIs) was performed using the extended Tofts model in the Olea Sphere 2.2 software permeability module (Olea Medical Inc.). The arterial input function (AIF) was obtained from the aorta or axillary artery. Estimated kinetic model parameters were transfer constant (K^{trans}), extracellular extravascular space volume fraction (v_e), plasma volume fraction (v_p), and the rate constant of contrast agent escape from the extracellular extravascular space into the plasma compartment (k_{ep}).

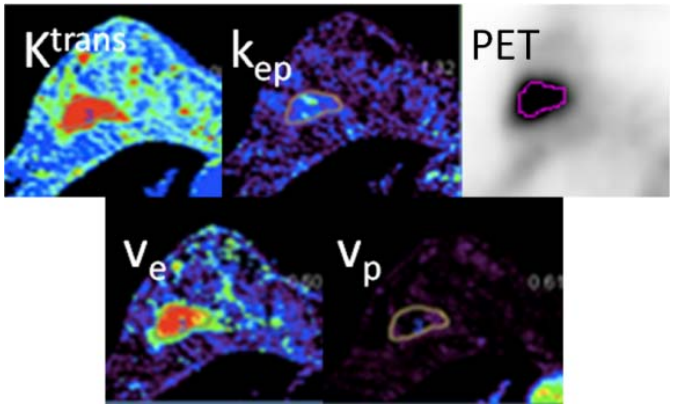

Figure 1: Simultaneously acquired axial DCE-MRI pharmacokinetic parameter maps and PET image of a Her2/neu+, Ki67+, PR+ right breast cancer

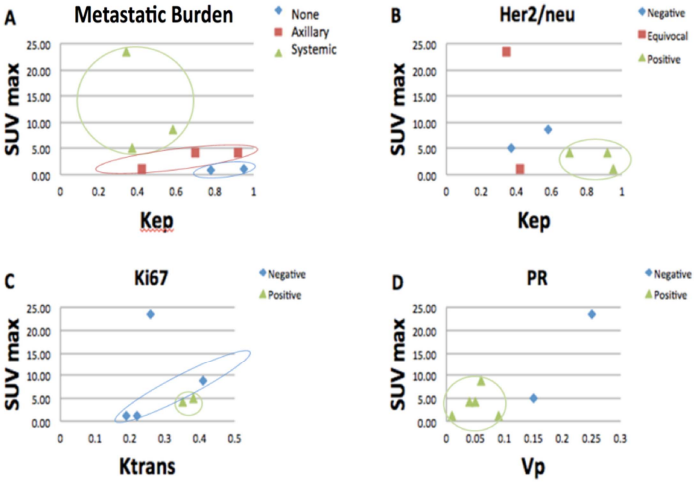

Figure 2: Scatter plot graphs of SUV max and (a) k_{ep} and metastatic burden, (b) k_{ep} and Her2/neu receptor status, (c) K^{trans} and Ki67 status, and (d) v_p and progesterone receptor (PR) status

Results: Figure 1 shows representative images from one patient with a 3 cm mixed invasive ductal carcinoma/invasive lobular carcinoma. The post-contrast DCE-MRI pharmacokinetic parameter color maps and PET scan (Fig.1) demonstrate the feasibility of generating DCE-MRI pharmacokinetic modeling data and FDG-PET uptake data to characterize malignant lesions. For instance, Fig.2a shows that a combination of k_{ep} and SUV max of the primary mass can be used to differentiate patients with no metastasis, axillary or systemic metastases, while no single parameter could separate these three groups. All patients with Her2/neu positive tumors had k_{ep} greater than 0.6, regardless of SUV max (Fig.2b). All progesterone positive tumors had a v_p of less than 0.1, regardless of SUV max (Figs.2d and 3a). Furthermore, all progesterone positive tumors had a k_{ep} of greater than 0.4, whereas progesterone negative tumors had a k_{ep} of less than 0.4 (Fig.3b).

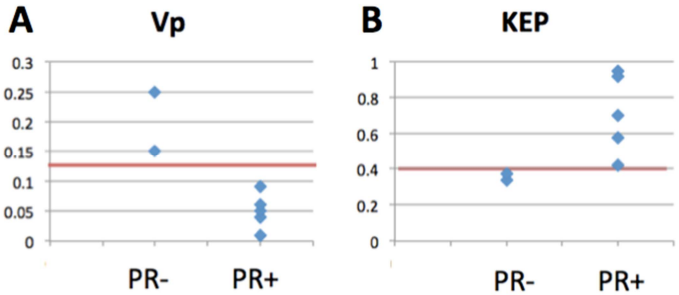

Figure 3: Scatter plot graphs of PR status and v_p (a) and k_{ep} (b)

Discussion: These preliminary results demonstrate the feasibility of using MR pharmacokinetic modeling and metabolic activity from simultaneous acquired DCE-MRI and FDG-PET for better characterization of breast lesions. Our feasibility data highlights the potential of using the combination of k_{ep} and SUV max to differentiate patients based on metastatic burden rather than using individual parameters alone. Also, the combination of MR pharmacokinetic data and PET may aid in the prediction of tumor subtype and prognosis, which may help in treatment planning and monitoring response. Future studies are warranted with a larger cohort to further assess the role of pharmacokinetic modeling in simultaneous PET/MR imaging.

References: [1] Moy L, Breast J. 2010; 16(4):369-76. [2] Pinker K et al Proc ISMRM 2011 #760. [3] Koo HR et al. J Magn Reson Imaging. 2012 Jul;36(1):145-51. [4] Chandarana et al Invest Radiol. 2011Oct;46(10):648-53. [5] Feng et al, Magn Reson Med. 2013, Epub ahead of print.