# 18F-FDG and 18F-NaF PET/MR Imaging of Osteoarthritis in the Knee: Considerations and Initial Results

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**Introduction:** Osteoarthritis (OA) is a disease of the entire joint that involves inflammation and bone remodelling such as subchondral sclerosis, cysts, and osteophytes. New PET/MR systems[1] allow for simultaneous, sensitive, and quantitative assessments of early bone activity in OA. $^{18}$F-FDG PET shows areas of acute phase cellular response (neutrophils or PMNs) in the bone marrow, such as inflammation[2]. $^{18}$F-NaF PET interrogates osteoblast activity in the bone[3]. This metabolic bone data from PET can be correlated with high-resolution quantitative MR methods[4] of other tissues to study the pathogenesis of OA. In this work, we demonstrate initial results of 18F sodium fluoride (NaF) and fluorodeoxyglucose (FDG) PET/MR knee imaging to detect and characterize osseous and soft tissue abnormalities in patients with knee OA. Considerations for PET-MR scanning of the knee are also discussed.

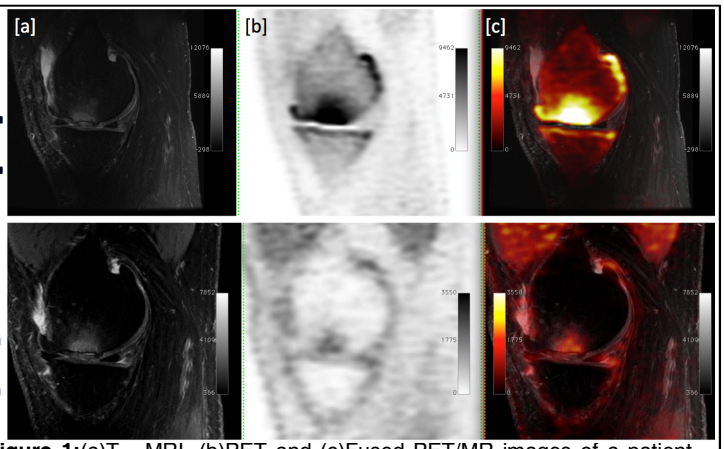


**Figure 1:**(a)$T_{2w}$ MRI, (b)PET and (c)Fused PET/MR images of a patient with moderate OA injected with NaF (top) and FDG (bottom)

**Knee PET/MR Considerations:** *PET Attenuation Correction:* In order to obtain accurate PET images, emission data recorded during a PET scan must be corrected for tissue and hardware attenuation. This is performed during reconstruction using an attenuation map (μ-map). Differences in PET attenuation between tissue fat and water as well as attenuation due to the PET/MR system are accounted for. Phantom and in vivo results showed that attenuation effects of the flex coil on standard uptake value (SUV) values and lesion area appear to be negligible. Investigations are ongoing to correct for cortical bone attenuation.

*Dose:* MR knee protocols (20-60 minutes) are considerably longer than the data collection time in one patient bed position in clinical PET-CT (3-4 minutes). As all of the MR scan time can be used to collect PET data, the injected radiotracer dose can be reduced by the equivalent increase in scan time (~5-15x). Our initial study uses a dose of 5 mCi (~1/2 standard clinical dose).

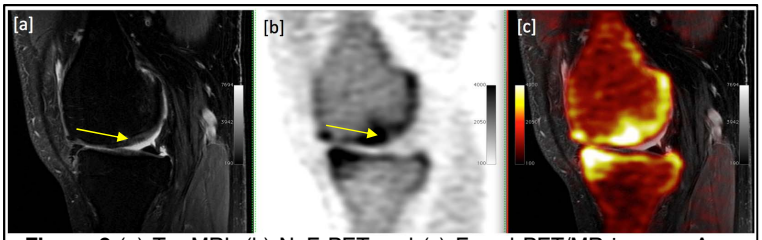


**Figure 2:**(a) $T_{2w}$ MRI, (b) NaF PET and (c) Fused PET/MR images. Arrow shows area of cartilage fibrillation correlating to increased NaF PET uptake

**Materials & Methods:** Simultaneous PET and MR imaging experiments were performed on a 3T PET-MRI hybrid system (GE Healthcare, Milwaukee, WI) using a 16 channel Flex coil under an approved IRB protocol. Two subjects with previous ACL tears and unilateral radiographic OA (Kellgren-Lawrence grade 2-3) were imaged following injection of 5 mCi $^{18}$F-FDG, and then several days later with $^{18}$F-NaF PET. Each knee was scanned with a 30 minute MRI protocol which included proton density and $T_2$-weighted Fast Spin Echo, quantitative Double Echo Steady State, a $T_{1\rho}$ prepared 3D-fast spin echo with variable flip angle refocusing, and the GE Silent sequence. Simultaneously imaging of the whole knee within one PET bed position (26 cm field of view) allowed the entire MR scan duration to be used for PET acquisition, while obtaining excellent image registration. SUV maps were generated from PET images by normalizing for the patient weight and injected tracer dose[5].

**Initial Results and Discussion:** Our initial results showed more regions of increased tracer uptake on NaF PET (12 abnormal foci) than regions of increased FDG uptake (5 abnormal regions) or regions of bone abnormalities on MRI (5 regions). Bone abnormalities observed on MRI consistently correlated with increased FDG and NaF PET tracer uptake (figure 1). However, the target to background ratio SUV in these regions was considerably higher with NaF than with FDG. Of significant interest, increased NaF uptake did not always correspond to structural damage detected on MRI or increased FDG uptake (figure 2). Of the 12 abnormal regions of NaF uptake, 9 were observed in the ACL injured knees compared to 3 in the contralateral knees. No bone abnormalities on MRI or increased FDG uptake were observed in the contralateral knees. The majority of these uncorrelated abnormal regions of NaF uptake were in the subchondral bone, a region that is associated with the development of pain as well as cartilage degeneration. In addition, correlation was observed between subchondral areas of increased NaF uptake and adjacent cartilage fibrillation (arrow-fig 2). Furthermore, SUV values were considerably higher in these areas in the subject with moderate OA (KL 3) compared to the subject with mild OA (KL 1-2). As NaF is related to osteoblast activity, areas of increased NaF uptake may also be signs of osteophyte formation. This suggests that metabolic abnormalities in the bone may occur prior to structural changes are seen on MRI. Work is ongoing to recruit more subjects to compare PET SUV in cartilage and subchondral regions to quantitative MR measures such as T2 and $T_{1\rho}$.

**Conclusions:** We demonstrate initial results of simultaneous time-of-flight PET/MR hybrid imaging of the knee. Results suggest that PET/MR may detect knee abnormalities unseen on MRI alone and is a promising tool for early detection of OA change in the bone.

**References:** [1] Pitchler et al. *J Nucl Med.* 2010;51 [2] Chong et al. *Int J Rheum Dis*. 2014;17(3). [3] Draper et al. *J Magn Reson Imaging*. 2013;36. [4] Shapiro et al. *J Magn Reson Imaging*. 2014;39(6). [5] Schomburg *Eur J Nucl Med* 1996; 23. **Research support:** GE Healthcare, NIH.

*__Disclaimer:__ Data acquired using an investigational device that is 510k pending at FDA. Not approved for sale. Not for sale in all regions.