Using ^{18}F NaF PET/CT to image increased bone activity in patellofemoral pain: Correlation with MRI

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Introduction:

Articular cartilage degeneration at the knee is associated with pain and the development of osteoarthritis (OA). Recent work suggests that cartilage health is affected by the integrity of the underlying subchondral bone[1,2]. MRI provides accurate structural information about the bones and soft tissues of the body; however, there may be alterations in bone activity accompanying pathological changes in tissue structure that are not visualized with MRI. Regions of bone remodelling with high metabolic activity can be detected using ^{18}F NaF PET/CT[3]; however, it remains unclear whether structural defects in bone and cartilage correspond to increases in bone metabolic activity. The goal of this study was to evaluate whether abnormalities in the knee detected using ^{18}F NaF PET/CT correlate with bone and cartilage defects detected using MRI in patients with knee pain.

Methods:

We acquired MRI and ^{18}F NaF PET/CT scans of both knees of 22 subjects diagnosed with patellofemoral pain (12 male: 31±8 years, 1.8±.09m, 78±12kg; 10 female: 34±8 years, 1.6±.04m, 60±6kg). Three knees were excluded due to surgery, for a total of 41 knees. For the PET scan, subjects received 5-10mCi of ^{18}F-NaF intravenously (0.08mCi/kg) and remained seated for 30 minutes prior to tracer injection and for 60 minutes between tracer injection and scan. PET scans (Figure 1a,c) were acquired using a GE Discovery LS PET/CT scanner: FOV: 18cm, pixel size: 4.3x4.3mm, slice thickness: 4.25mm, 5 minute acquisition, ordered subsets expectation maximization iterative reconstruction. Corresponding CT images were obtained: 140kVp, 90mAs, slice thickness: 5mm, FOV: 50cm, reconstruction matrix: 512x512. MR images (Figure 1b,d) were acquired using a GE Signa HDx 3.0T MRI scanner and an 8-channel knee coil. Scans sensitive to bone marrow edema and cartilage damage were acquired using fat-suppressed, fast spin-echo sequences: (Axial proton-density) TR: 4200ms, TE: 35ms, slice thickness: 4mm, flip angle: 90º, matrix: 416x320, FOV: 14cm and (Sagittal T2-weighted) TR: 7000ms, TE: 77ms, slice thickness: 4mm, flip angle: 90º, matrix: 320x224, FOV: 16cm.

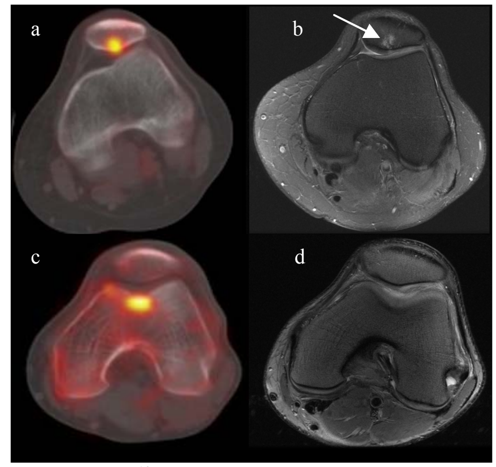

Figure 1: ^{18}F NaF PET/CT image (a) and corresponding high-resolution MR image (b). Increased tracer uptake (yellow/red overlay) found on posterior patella in PET/CT image indicating increased bone activity. Tracer uptake corresponds to bone marrow edema (arrow) detected with MRI. ^{18}F NaF PET/CT image (c) with increased tracer uptake in trochlea. Corresponding MR image (d) showing no bone or cartilage defects.

Each knee was divided into 26 anatomical regions (Patella: 12, Femur: 10, Tibia: 4) and the bone or cartilage integrity within each region was rated with each modality using a 3-point scoring system. The PET/CT images were assessed by a nuclear medicine radiologist using the following scoring system: 0 = no signal uptake, 1 = uptake above soft-tissue background, 2 = uptake above bone background. A musculoskeletal radiologist, blinded to the PET/CT scores rated the bone and cartilage from the MR images (Bone: 0 = no edema, 1 = edema <50% total volume, 2 = edema >50% total volume; Cartilage: 0 = healthy, 1 = fray/fissure, 2 = partial or full thickness loss). We correlated the scores from the PET/CT images to the bone and cartilage scores obtained from MRI. PET/CT only enables bone to be assessed; therefore, regions of bone closest to the cartilage regions were used when comparing cartilage and bone abnormalities.

Results:

The regions of signal uptake on the PET/CT scans (hot spots), indicating increased bone activity, correlated with bone marrow edema, subchondral cysts, and/or cartilage damage. The comparison of PET/CT scores with MRI scores is highly asymmetric (Table 1), indicating that increased bone activity does not always correspond to structural damage in cartilage or bone marrow edema seen with MRI. There were 22 intense PET/CT hot spots with no corresponding bone structural abnormality detected by MRI (Figure 1c,d), whereas there were no severe bone abnormalities (score = 2) seen on MR that did not also exhibit increased bone activity (Table 1a). This asymmetry existed in the comparison of both the cartilage and the bone scores with the PET/CT scores ($p<0.00001$); however, the comparison between cartilage and bone integrity scored from MRI was symmetric ($p=0.65$), indicating a more consistent relationship between bone marrow edema and cartilage damage.

a) MRI Bone Score

PET Score	0	1	2
0	985	19	0
1	27	1	0
2	22	6	6

b) MRI Cartilage Score

PET Score	0	1	2
0	987	14	3
1	26	2	0
2	20	11	3

Table 1: Bone (a) and cartilage integrity (b) scores obtained from MRI compared to corresponding PET/CT scores. All subjects and all regions are combined. Note the asymmetry in the tables ($p < 0.00001$), indicating that PET/CT revealed more abnormalities than MRI.

Discussion:

Our results indicate that ^{18}F NaF PET/CT may provide information different from bone marrow edema and structural cartilage changes seen on MRI in patients with knee pain. ^{18}F NaF PET/CT may be a promising technique to image metabolic abnormalities in the bone, prior to the development of structural damage seen using MRI. Other MRI techniques, such as spectroscopy, may be more sensitive to metabolic changes[4], and may be able to detect bone abnormalities without ionizing radiation. Future research is needed to evaluate whether increases in bone metabolic activity accurately predict the development of cartilage and bone damage in the presence of knee pain.

Acknowledgements: Jarrett Rosenberg for statistics advice. NIH (EB002524-01, EB005790-01), Department of Veterans Affairs (#A2592R), GE Healthcare.

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