

Atherosclerotic Plaque Imaging with Integrated PET/MR: Preliminary Results in a Rabbit Model

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Objectives: Atherosclerosis is the main cause of death in the western world. Characterization of the so-called “vulnerable” atherosclerotic plaque, which is at risk for disruption, is critical to predict acute adverse events. High-resolution MRI has shown ability to identify and discriminate components of complex atherosclerotic plaques [1,2]. In molecular imaging using positron emission tomography (PET), the metabolic tracer 18F-FDG was shown to accumulate in highly inflamed plaques and therefore has been proposed as a mean to characterize the extent of inflammation [3,4]. The aim of this study was to demonstrate the ability to identify complex, vulnerable plaques in a rabbit model of carotid artery atherosclerosis combining morphological and functional information in simultaneous PET/MR imaging.

Methods: Animal studies were approved by the local government agency. Two rabbits were put on a high-cholesterol diet, rabbit 1 for four weeks, rabbit 2 for eight weeks. Subsequently, for both rabbits, the left carotid was injured with balloon denudation and after another four weeks of lower cholesterol diet, imaging was performed on a human whole-body simultaneous PET/MR scanner (Biograph mMR, Siemens, Erlangen, Germany). After injection of 150 MBq 18F-FDG, dynamic list mode emissions scans were acquired for up to 120 minutes post tracer injection. Simultaneously, MR imaging was performed using a dedicated human carotid coil (4-channel, Machnet BV, Eelde, The Netherlands). An 18-s Dixon sequence was acquired to obtain a μ -map for attenuation correction (AC) of PET data [5]. A time-of-flight (TOF) angiographic sequence was used to show vessels and degree of luminal stenosis: 2D multi-slice, axial, TR/TE 533/7.2ms, FOV 125x250mm², resolution 0.65x0.65mm², slice thickness 3.5mm, BW 114Hz/px. Then, turbo spin echo (TSE) sequences with T1- and T2-weighting were acquired: 2D multi-slice, axial, TR/TE 800/13ms for T1w and 4500/68ms for T2w, turbo factor 13, FOV 84x120mm², resolution 0.31x0.31mm², slice thickness 2mm, BW 130Hz/px, averages 2. In TSE sequences, dark blood was achieved using either saturation bands (T2w) or double inversion recovery (T1w) preparation. The attenuation corrected PET images were fused with the MR images. Histological analysis was performed on the excised carotid arteries.

Results: Fusion of simultaneously acquired PET and MR data lead to an exact localization of the vessel on lower resolution PET images using the anatomical information from high-resolution MR images (Fig. 1d,h). The two rabbits presented very differently on the imaging results. The four week cholesterol fed rabbit 1 showed no stenosis on TOF (Fig. 1a), but enhanced signal uptake on MRI (Fig. 1b,c) and PET images (Fig. 1d) in the injured left carotid. The eight week fed rabbit 2 showed obstructed blood flow in both carotid arteries (Fig. 1e). Collateral vessels supplied blood flow and in axial TSE images plaque was observed around these collateral vessels. In this rabbit, only diffuse PET and MRI contrast agent uptake was observed (Fig. 1g,h). Histological analysis confirmed imaging results, showing large inflamed plaque in injured left carotid in rabbit 1. In rabbit 2, obstructing, inflamed plaque with neovasculature was found.

Conclusions: Our preliminary results revealed good agreement between non-invasive imaging using simultaneous PET/MR and histology of complicated atherosclerotic plaques. Integrated PET/MR imaging is especially attractive in plaque imaging, since plaques are small and inherent image fusion enables to combine high-resolution morphological information from MR images with functional information from low resolution PET images. The multimodal approach is able to characterize complicated plaques by identifying the degree of stenosis and plaque morphology using MRI, as well as increased metabolic activity indicating inflamed plaque using 18F-FDG PET.

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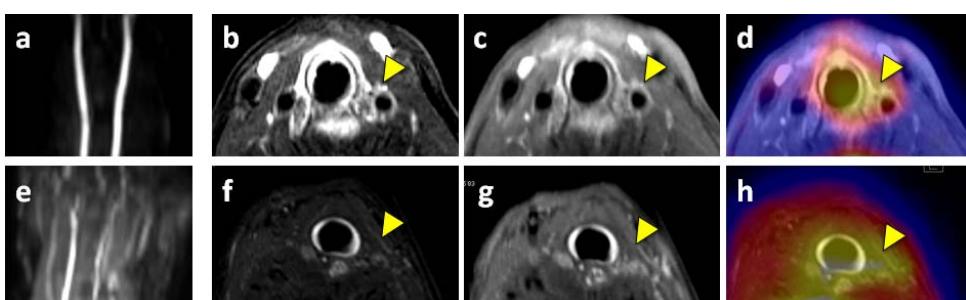


Figure 1. Multimodality imaging in four week cholesterol-fed rabbit 1 (a-d) and eight week cholesterol-fed rabbit 2 (e-h): Time-of-flight (TOF) MRI shows normal blood flow in rabbit 1 (a) and obstructed flow in rabbit 2 (e). High resolution T2w TSE MRI (b,f), T1w TSE MRI post injection of Gd-based contrast agent (c,g) and fusion of PET 18F-FDG static emission scan with T2w TSE MRI (d,h). Yellow arrows point to enhanced imaging signal in vessel wall of balloon injured left carotid artery in shorter fed rabbit 1 (b-d), while diffuse uptake is observed in rabbit 2 (f-h).