Characterization of atherosclerosis lesions with TrueFISP Intravascular MRI

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Introduction. Atherosclerosis, the deadliest disease of western civilization, can be well characterized by a variety of MR imaging methods. MRA can assess lumen stenosis, while multi-contrast images (e.g. T1W, T2W, and PDW) can identify the main tissues present in vessel wall lesions: fibrous tissue, lipid core, and calcification (1). We are investigating vessel wall imaging with intravascular MRI using microcoils mounted on a 5Fr catheter. Steady state free precession fast acquisition sequences are used in our trials because of motion and constraints of real-time intervention, (SSFP/TrueFISP) (2). From *in vivo* experiments in pig models we routinely observe a hypo-intense layer surrounding an inner hyper-intense one (Fig. 1) in large vessels. Here we have significantly extended earlier work by conducting experiments to elucidate the structures corresponding to these layers and to characterize atherosclerotic lesion tissues in *ex vivo* cadaver samples using TrueFISP acquisitions.

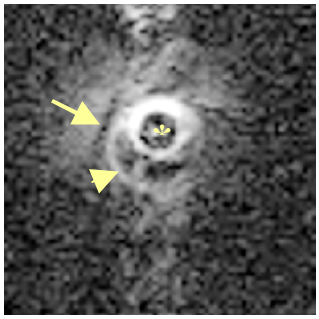

Fig 1. Example of *in vivo* imaging in pig carotid using TrueFISP. Hypointense (arrow) and hyper-intense (arrow head) layers can be seen on the vessel wall. * shows the catheter.

Methods. In vivo and post mortem experiments: Over ten 40-55 kg farm pigs were anesthetized and imaged (IACUC approved protocol) with a Siemens Espree scanner using a 5Fr catheter mounted with opposed double solenoid microcoils (interventional Imaging Inc., Cleveland, OH) (2). Tracking was done under fluoroscopy and/or MRI to position the catheter tip at different arterial locations (e.g. carotid, aorta,…). Multi-slice images axial to the catheter/vessel were acquired using TrueFISP (TR, 15 ms; TE, 8 ms; flip angle, 70°) (2). Images were taken *in vivo* and *post mortem in situ* with resolution typically about 0.2x0.2x3mm^3 and fields of view of ~5.5cm. Ex vivo imaging: Four human iliac artery samples were obtained at autopsy from human cadavers upon consent from family, positioned on a rig and into a plastic container filled with OCT gel and imaged at 37°C. High resolution 3D TrueFISP volumes were acquired (0.26x0.26x0.3mm^3) with surface coils and intravascular 12Fr microcoils. Cryoimaging: Immediately following ex vivo MR imaging, the samples (including plastic holder) were flash frozen in liquid nitrogen, mounted in a cryo-microtome and high resolution (0.04x0.04x0.2mm^3) bright field and fluorescence images of the block face were obtained. Image analysis: Stack of cryoimages were corrected for illumination, serially registered, normalized and registered using 3D rigid body transformation to the 3D TrueFISP volume. From cryoimages, vessel tissues could be identified: Adventitia (Ad), Media (Md), Calcification (Ca), Lipid Core (Lc), and fibrous tissues (Ft). Means of regions of interest (ROI) drawn on the corresponding MR images and 3 intensity ratios were computed: Md/Ad, Ca/Ad, and Ft/Ad. Coil sensitivity was taken into account by correcting the ratios with signal intensity from the medium adjacent to each side of the vessel wall.

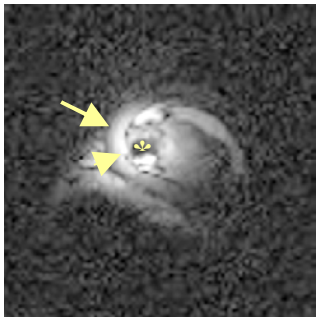

Fig 2. The same structures can be observed *post mortem in situ* in this pig aorta after euthanasia. Same legend as in Fig 1.

Results and discussion. *Ex vivo* TrueFISP images consistently show the hyper-intense /hypo-intense regions present in vivo. With accurate registration to the cryo-images (Fig. 3), we can identify a hypo-intense layer as the adventitia, while the tunica media has a hyper-intense signal. These results were readily seen by comparing registered cryoimaging and TrueFISP volumes (Fig 3.) and confirmed by quantitative analysis: the ratio Md/Ad was found to be 1.37 (+/-0.18) using the surface coils. Despite higher SNR, quantitative analysis with intravascular microcoils is more challenging because of the steep sensitivity profile. However comparable intensity ratio can be observed in vivo (Fig. 1) and post mortem (Fig. 2). Other signal ratios from the *ex vivo* experiment were found to be: Ca/Ad=0.53+/-0.09, Lc/Ad=0.93+/-0.11, and Ft/Ad=1.32+/-0.20. We conclude from these results that using TrueFISP, the tunica adventitia appears as a hypo-intense while the tunica media appears as hyper-intense. Furthermore, Ca and possibly Ft and Lc might be characterized with TrueFISP, and with earlier work, further positions TrueFISP for application in cardiovascular intervention.

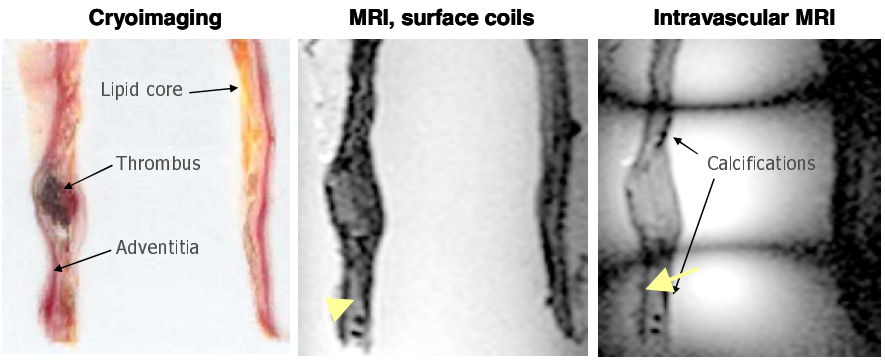

Fig 3. Sagittal view of one *ex vivo* sample. Left panel shows the cryoimaging volume where different tissues can be identified. Middle and right panels show the corresponding sections from the registered MRI TrueFISP volumes (intravascular MRI is log transformed). Arrow and Arrow head have been put on Adventitia and Media layers.

References. (1) Yuan C. et al, JMRI, 2004,19(6):710. (2) Hillenbrand et al., JMRI, 2006, 23(2):135.