Fluorine Coronary MR-Angiography with Nanoparticle Contrast Agents at 1.5 T

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Introduction:

Fluorine MRI has been used for a variety of applications, the most widely recognized of which is studying tissue oxygenation [1-3]. The low natural abundance of ^{19}F in physiological tissues, however, often necessitates the use of high magnetic field strengths and/or the use of highly concentrated fluorinated contrast agents. We have previously developed a novel perfluorocarbon nanoparticle contrast agent which contains a very high concentration of fluorine [4], and which can therefore be used at clinical field strengths for ^{19}F MR imaging. In this work, we demonstrate the use of this agent for ^{19}F coronary MR-angiography.

Methods:

To enable ^{19}F imaging on our clinical 1.5 T Philips MR scanner, the system was modified to include a specialized channel tuned for fluorine nuclei, and we developed a series of surface and volume RF coils tuned to the same frequency (60.1 MHz). To gauge the minimal limits of detection of this system for fast ^{19}F imaging, we imaged samples of perfluorocarbon nanoparticles (20% v/v perfluoro-15-crown-5-ether; diameter ~250 nm, 18.2 M fluorine concentration) diluted in water using an FFE sequence and a 5cm transmit and receive (T/R) surface coil (TR=9.8ms, TE=3.2ms, block pulse with estimated 80° flip angle, resolution= 0.81x1x40 mm). For the angiography experiment, the undiluted crown ether nanoparticles were slowly hand-injected through a 2 F diameter balloon catheter into the left main coronary artery of an isolated pig heart. During injection, a series of dynamic "balanced" FFE ^{19}F projection scans (TR= 4ms, TE= 1.5 ms, matrix= 2x2.5x70 mm, 2.8 s per dynamic) were acquired using a 13cm T/R Helmholtz coil.

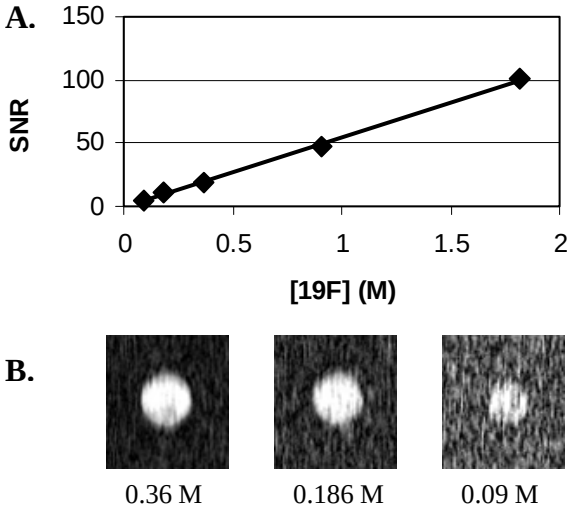

Figure 1: A) Signal to noise ratio versus fluorine concentration in images of nanoparticle phantoms. **B)** Images corresponding to the three lowest concentrations depicted in part **A**.

Results:

Figure 1 shows the results from the "minimum detection" imaging experiment. The signal to noise is linear with respect to fluorine concentration (or, nanoparticle dilution) with a slope of 55.03 and an $R^2 > 0.99$ (panel A). Sample images obtained from the three lowest concentrations used are shown in panel B. Figure 2 shows the results from the angiography experiment. Panels A-D show the injection of the particles into the coronary artery of the pig heart (elapsed time is approximately 30 seconds) as they proceed down the LAD and into smaller vessels. Panel E shows a corresponding ^{1}H image of the heart.

Conclusions:

We have demonstrated a method for ^{19}F-based coronary MR angiography that requires neither fat suppression nor other preparatory pulses using PFC nanoparticles. The high signal to noise level obtained with this fast scanning technique provides incentive for further modifications including higher resolution and/or near real-time imaging of vascular filling. Our preliminary data on the minimum detection limits for imaging of the nanoparticles with this system also indicates that this technique may be feasible *in vivo*, where the nanoparticles will be diluted substantially by flowing blood. Ultimately, peripheral injections of nanoparticles may provide an improved method for noninvasive coronary MRA.

References:

1) Dardinski BJ, Sotak CH. *Magen Reson Med* 1994. 32(1):88-97.
2) Mason RP, Hunyan S, Le D, et al. *Int J Radiat Oncol Biol Phys* 1998: 42(4):747-50.
3) Noth U, Grohn P, Jork A, et al. *Magn Reson Med* 1999. 42(6):1039-47.
4) Flacke S, Fisher S, Scott MJ, et al. *Circulation* 2001. 104(11):1280-1285.

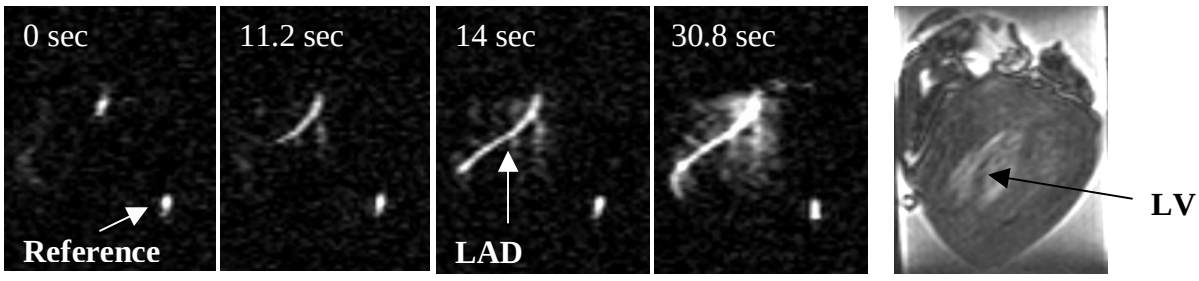

Figure 2: A-D) Time elapsed ^{19}F images acquired during injection of fluorinated nanoparticles into the left coronary artery of an excised pig heart. **E)** Corresponding ^{1}H image (single coronal slice through left ventricle).