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Magnetic Resonance Angiography in the Pig using Hyperpolarized Water

Kasper Wigh Lipsø[1], Sean Bowen[1], Christoffer Laustsen[2],
Esben Søvsø Szocska Hansen[2], Thomas Nørlinger[2] and Jan Henrik Ardenkjær-Larsen[1,3]
[1]Department of Electrical Engineering, Technical University of Denmark, Ørsteds Plads, 2800, Kgs. Lyngby, Denmark
[2]Department of Clinical Medicine - The MR Research Centre, Aarhus University, 8200, Aarhus, Denmark
[3]GE Healthcare, Brøndby, Denmark

Introduction Magnetic Resonance Angiography (MRA) is an important tool in diagnostics of medical conditions such as emboli, stenosis and aneurysms. Sub-millimetre resolution can be obtained with proton imaging, and further optimization can be obtained with Gd-based blood pool agents[1]. However, the acquisition time is several minutes, and conventional MRA methods thus fail to image within a single respiration or heartbeat and therefore suffers from motion artefacts.
We demonstrate that hyperpolarized (HP) water can be used as an imaging agent to provide subsecond angiographies in pigs. Previous work on hyperpolarization for imaging agents in large animals has mainly been focused of ^{13}C [2,3], but small volumes of hyperpolarized water with lower polarization has been demonstrated[4,5]. Injection of hyperpolarized protons allows for the use of MRI coils and pulse sequences already existing in the clinic. Secondly, the magnetization achievable with hyperpolarized water is superior to other nuclei.

Methods A 1 mL sample of 50% water and 50% glycerol with 30 mM TEMPO is polarized in a Spinlab (GE Healthcare) at 5 T, 0.9 K, 139.9 GHz for an hour. The sample is rapidly dissolved in 16 mL deoxygenized dissolution medium (DM) consisting of 1 mM EDTA, 50 mM sodium L-ascorbate, 1.9 mM NaH_2PO_4 and 8 mM Na_2HPO_4 dissolved in D_2O. The DM is filled in the syringe with 7.6 g nonaflourobutyl methyl ether, which will accelerate the dissolution process and extract radical from the polar phase, and hence extend the T_1. 10 mL deoxygenized heptane is added to the receiver to further extract the radical.
The polarization is quantified in two ways: 1) the signal integral (FID amplitude) is compared to a thermally polarized, pure water reference sample (110 M) and 2) the line width due to radiation damping is compared to the radiation broadening of a thermally polarized, pure water sample. The two methods agree.
Proton concentration is quantified by NMR measurement of the dissolved sample added a reference molecule.
The images are acquired on a 3 T MRI system (GE healthcare) with a 4 channel array surface coil with a gradient echo sequence with 5 ° flip angle, slice thickness of 40 mm, TR = 3.4 ms, TE = 0.9840 ms, 256x256 matrix, FOV = (140 mm)^2. The acquisition time is 870 ms. 15 mL HP substance is injected over 5 s, initiated 15 s after dissolution through a catheter in the right renal artery of a 40 kg pig.

Results The protons are polarized by dissolution DNP to an enhancement of more than 2000 times at 9.4 T, corresponding to a polarization of 13% at time of injection. T_1 of ~20 s is achieved in vitro for a ^1H concentration of 4.5 M. A zoom of a renal MRA is shown in **Figure 1**. The image maps minor branches of the renal arteries, and the perfusion can be traced over time (time series not shown).

***Figure 1**. Renal angiography in a pig*

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References

[1] Howles, G. P., Ghaghada, K. B., Qi, Y., Mukundan, S. & Johnson, G. A, Magn. Reson. Med. 2009, 62:1447–1456.
[2] Olsson, L. E. et al., Magn. Reson. Med. 2006, 55:731–737.
[3] Golman, K. et al., Magn. Reson. Med. 2001, 46:1–5.
[4] Ardenkjaer-Larsen, J. H., Laustsen, C, Bowen, S & Rizi, R, Magn. Reson. Med. 2014, 71:50-56.
[5] Harris, T, Szekely, O & Frydman, L, J. Phys. Chem. B 2014, 118:3281−3290.