MRI endoscopy at 3T

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Introduction: Until now MRI could not perform traditional endoscopy from the viewpoint of an internal probe because localization depended entirely on the fixed external gradient system and was hence intrinsically locked to the laboratory frame-of-reference (FoR). A method for high-resolution MRI using active internal probes that utilizes the spatial properties of the probe itself, for MRI has been proposed [1]. Because these properties are intrinsic to the probe, they move with it, transforming the MRI FoR from the laboratory to the device, creating a true MRI endoscope. The endoscope has been reduced to safe practice at 3T yielding high resolution (100µm) intravascular images.

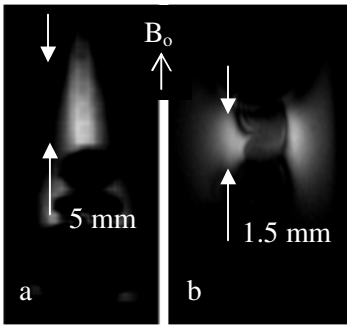

Fig 1: Full-width-half-max excitation slice width of modified loopless antenna (a) and multi-turn loop (b) as measured by projection MRI.

Methods and Results: Transmit/Receive endoscopic probes with inherently localized sensitivity in an axial substantially-disk-shaped "slice" are fabricated in two forms. First, a four-turn loop catheter coil [2] is built of insulated wire and tuned to 128MHz with a 51pF capacitor. Second, a 3T loopless catheter antenna [3] with a λ/4 sleeve-balun comprising copper tape rolled over PTFE dielectric is constructed. For excitation, we use adiabatic BIR-4 pulses [4] (duration, 4ms; frequency sweep ± 15 kHz) to provide a substantially homogeneous flip angle over the slice. The combined effect of RF transmission and detection by the probes confines their signal in the dimension parallel to the probe's axis, as measured by conventional projection MRI (Fig 1). Conventional gradient encoding employed in the other two directions generates an image at an arbitrary location in the field-of-view which is easily moved to the image center based on signal intensity. Thus, knowledge of the probe's location in the scanner is unnecessary as the probe inherently acquires an image of what it 'sees'. As the probe moves, the imaged slice moves with it, thereby transforming the FoR to the probehead.

The probes are interfaced to a Philips 3T *Achieva* system via a custom interface with additional preamplifiers for a total system gain of 80dB and a noise figure of 0.9dB. The device/method is tested in a kiwifruit (Fig 2; type 1 device) to evaluate its ability to resolve heterogeneous tissue structure. *Ex-vivo* studies are performed with the probe in an intact porcine aorta, post mortem (Fig 3; type 2 device) showing clear resolution of the vessel wall at 100 µm with the probe parallel to the main field, B_O. When the probe is skewed relative to B_O, the "slice" is no longer entirely in the transverse plane, resulting, primarily, in some image blurring when the conventional gradients are used to localize the other two dimensions. The blurring (causing ~25% SNR loss in a resolution phantom 20º off-axis) can be ameliorated by occasionally updating the plane orientation. The time to perform endoscopy depends entirely on imaging parameters since no additional time is needed for probe tracking and the method can be made real-time by faster acquisition strategies.

Excitation by the tiny internal probes requires low power (0.25W r.m.s), greatly reducing eddy currents and Specific Absorption Rate (SAR), compared to whole-body excitation. Minimal temperature rise (~0.1ºC) is measured with the endoscopic probes operating continuously for 10 minutes in an agarose gel phantom. Peak experimentally calculated SAR is 0.5W/kg at the probe tip.

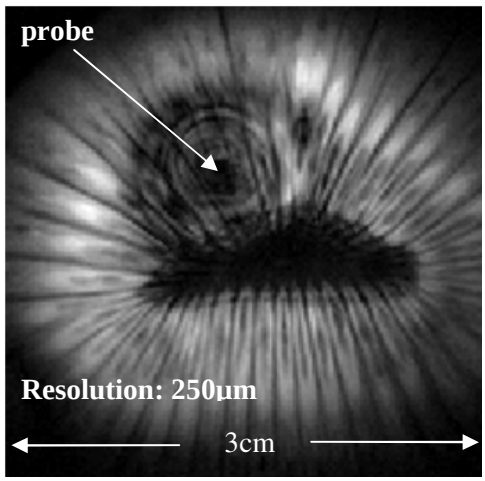

Fig 2: Gradient echo MRI of kiwifruit. Slice localization arises entirely from probe sensitivity. TR/TE = 3000/12 ms. FA 80º.

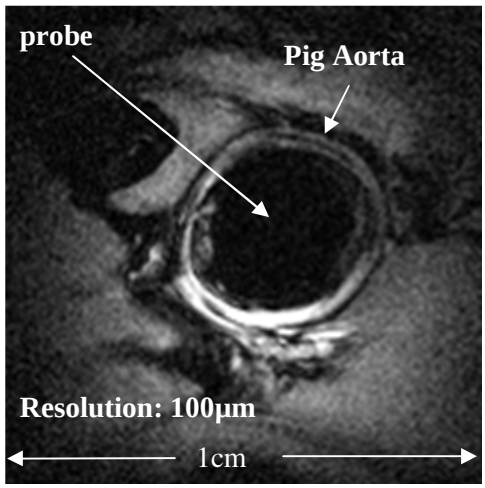

Fig 3: MRI endoscopy of a porcine aorta. TR/TE = 500/20 ms. FA 20º. FOV 15mm.

Conclusion: RF transmission and reception by modified internal probes inherently localizes the MRI signal to the probe-head, creating an MRI endoscope. The method is tested at 3T in a kiwifruit and in an intact porcine aorta demonstrating high resolution, with no significant heating. The method offers the potential for real-time, efficient, high-resolution MRI endoscopy with much lower power deposition than occurs with the probe when using conventional body excitation.

References: [1] Sathyanarayana S, et. al. Proc ISMRM 15, 2007; pp 492. **[2]** Kantor H. L., et. al. Circ. Res. 1984 ; 55:261-266. **[3]** Ocali O, Atalar E. Magn Reson Med 1997; 37:112–118. **[4]** Garwood M, Ke Y. JMR 1991; 94:511-525. *Supported by NIH grant R01 RR15396*