High resolution detection of kidney microstructures in vivo with a Wireless Amplified NMR Detector and Mn-enhanced MRI.

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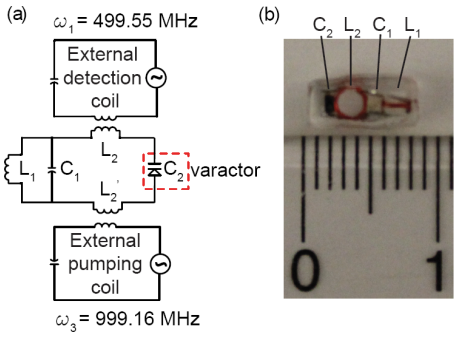
Target Audience:

Renal Physiologists, MR physicists, RF Engineers.

Purpose:

To observe kidney microstructures at high resolution *in vivo* with an implanted Wireless Amplified NMR Detector (WAND) combined with Mn-enhanced MRI.

Methods:



Conventional MRI doesn't typically observe kidney microstructures, such as glomeruli and renal tubules. This is due to the deeply buried kidney that is distantly separated from the external detection coil. Recently, a wireless amplified implantable detector has been developed to observe internal organs at a close distance [1]. It utilizes inductive pumping power to amplify the weak MR signals *in situ*. The WAND is a nonlinear double frequency resonator (Fig, 1a). The high resonance mode is to harvest the wirelessly provided pumping power at 999.16 MHz and the low resonance mode is to receive the weak MR signal and transmit the amplified signal at 499.55 MHz. The millimeter scale PDMS coated WAND (Fig, 1b) was then chronically implanted onto the medial surface of a rat kidney for *in vivo* imaging. The rat was placed under ventilation with 2% isoflurane and secured in supine position with a restraint belt wrapped about its abdomen to reduce motion. Coaxial, 22 mm diameter detection and pumping coils were placed externally beneath the kidney. A low-resolution 2D multi-slice FLASH image was acquired without pumping power to locate the WAND (Fig. 2a). Subsequently, high resolution images T_1-weighted (TE = 3.1 ms, TR = 41.2 ms) were acquired in the presence of pumping power both pre- and post- administration of $MnCl_2$.

Results:

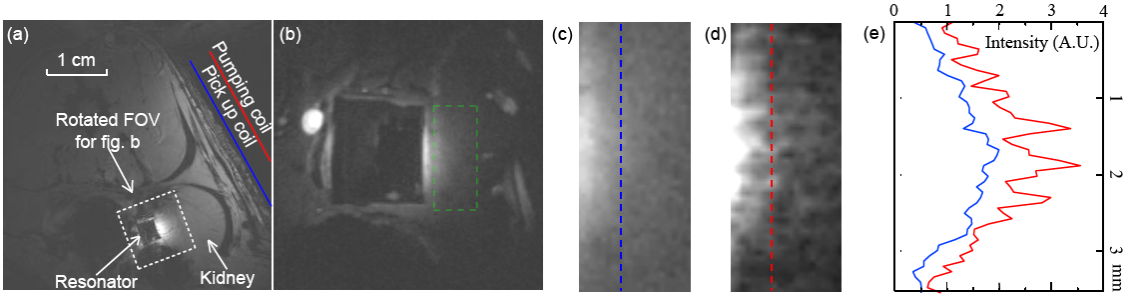


Fig. 2. (a) A low resolution image acquired without pumping power, using TR = 357 ms, TE = 6 ms, FA = 30 deg, slice thickness =1 mm, FOV = 4 x 4 cm², matrix size = 256 x 256. (b) A high resolution T_1-weighted image acquired with pumping power, using TR = 41.2 ms, TE = 3.1 ms, FA = 40 deg, slice thickness = 0.2 mm, FOV = 9 x 9 mm², matrix size = 128 x 128. (c) Zoomed in view of the region enclosed in the green box in Fig. (b). (d) A high resolution image acquired with the same parameters as Fig. (c) but after the administration of $MnCl_2$. (e) The 1D intensity profile along the blue dashed line in pre-contrast image and along the red dashed line in post-contrast image.

The kidney has little intrinsic contrast on T_1-weighted images before the injection of any contrast agent, except for blood vessels which show up as bright spots in the zoomed-in view of Fig. 2b. Twenty minutes after bolus injection of $MnCl_2$ at 75 umol/kg of body weight, bright ribbons show up (Fig. 2c) and they are surrounded by numerous dark spots that do not enhance as much. According to the 1D intensity profile (Fig. 2d), both the bright and the dark regions have higher intensity than pre-contrast image, but the bright regions have a larger increased intensity.

Discussion:

The bright ribbons can be tentatively assigned as renal tubules and the darker spots as glomeruli. The higher intensity in bright strips is probably due to Mn^{2+} in renal tubules and the different enhancement is probably due to reabsorption of Mn^{2+}.

Conclusion:

The WAND enables high resolution detection of kidney microstructures *in vivo*. More study is underway to assign the contrast detected with Mn^{2+} and to determine if contrast changes are useful to study renal function.

Reference:

1. Qian et al. Sensitivity enhancement of remotely coupled NMR detectors using wirelessly powered parametric amplification, *Magn. Reson. Med.* 68 (2012) 989-996.