A Transmit-Only/Receive-Only Radiofrequency Coil Configuration for Hyperpolarized 129Xe Imaging of the Rodent Lung.

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Target audience: MR hyperpolarized ^{129}Xe imaging and RF coil design.

Introduction: Hyperpolarized ^{129}Xe is a useful inhaled contrast agent for imaging of the lung airspace and has been shown to be useful for diagnosis of lung diseases, including chronic obstructive pulmonary disease, asthma and lung injury. In addition to imaging the lung airspace, ^{129}Xe promises to provide unique functional information due to its solubility and significant chemical shift (~200 ppm) in pulmonary tissue and red blood cells (RBC), [1]. Thus, this new technique is expected to be sensitive to early gas exchange changes accompanying radiation-induced lung injury. However, imaging of dissolved ^{129}Xe in the lung and blood is challenging due to low signal-to-noise ratio (SNR). We report a novel radiofrequency (RF) transmit-only/receive-only (TO/RO) coil configuration providing excellent transmit efficiency and uniformity as well as high sensitivity for hyperpolarized ^{129}Xe MR lung imaging of rodents at 3T (35.34 MHz).

Methods:

Numerical Simulation: RF transmit (B_1) field maps for the coil configuration were generated using a simulated electric current flow of 1 [A/m^2]. This B_1field simulation was computed by solving Biot-Savart laws in 3D using finite element modelling (Comsol Multiphysics) for both transmit and receive coils as shown in Fig 1 [4].

RF Coil design and construction: The TO/RO coil construction consisted of three components: (i) a high-pass birdcage transmit coil which produces a homogeneous B_1 magnetic field and can be used in both transmit/receive (T/R) and TO/RO modes, (ii) a saddle-shaped single-turn receive-only surface coil that couples closely to the rodent lung, and (iii) RF shielding as shown in Fig 1. On transmit, the receive-only coil is decoupled from the transmit coil using a detuning circuit [3]. On receive, the bird-cage coil is deactivated through the use of PIN diodes [2]. Switching between transmit and receiving modes was achieved using a MOSFET switch circuit by setting the DC component of the transmit signal as a gate voltage.

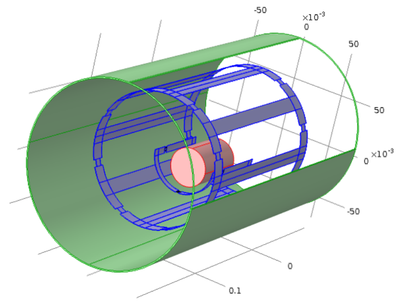

Fig 1. Simulation geometry.

MRI Acquisition: MR spectra and images from both the TO/RO coil and a commercially-made T/R birdcage coil were acquired from a pressurized ^{129}Xe thermal phantom using a 3T MRI system (MR750 GEHC). In vivo rat lung (healthy Sprague Dawley) hyperpolarized ^{129}Xe coronal images obtained following an animal care protocol approved by the Animal Care and Use (Western University). SNR and power efficiency were measured using a single hard pulse/acquire sequence (rectangular pulse width was 144µs). A 2D fast gradient-recalled echo sequence was used to acquire the sensitivity maps of thermal phantom using both TO/RO and T/R coil configurations (TR=4s, TE = 2.5 ms, FOV = 10cm x 10cm, matrix of 64x64, BW=2.0kHz, number of averages was 4).

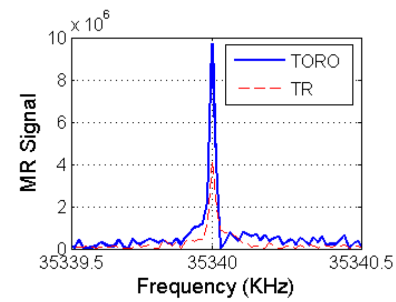

Fig 2. MR Spectrum of TO/RO and T/R.

Results and Discussion: Fig. 2 shows typical spectra obtained using the TO/RO and T/R coils. As expected, the TO/RO coil design provides an SNR improvement of a factor of approximately two compared to the commercially-made T/R birdcage coil, consistent with improvement in Quality factor (Q). An axial view of the phantom obtained with the TO/RO coil is shown in Fig. 3(a). For comparison, the simulated dependence of the coil sensitivity in the A/P direction is shown in Fig. 3 (b).

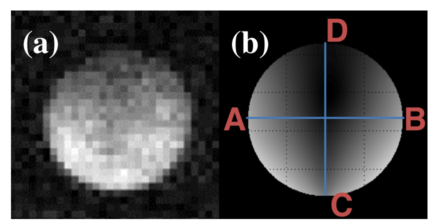

Fig 3. (a) Axial view of 2D projection MR image of the phantom; (b) Sensitivity map of the region of axial image (simulation).

Table 1. Comparison of SNR using TO/RO and T/R coils.

	SNR_{Lung}	$SNR_{Phantom}$	$Signal[A.U]$	$Noise[A.U]$	Q
TO/RO	10.9	38.5	2160000	56099	1767
T/R	5.3	19.8	776890	39081	519

Conclusion: These results show that the TO/RO configuration provides two fold increase in SNR without compromising transmit uniformity and efficiency compared to a T/R configuration. Although the receiver sensitivity is less uniform compared to the T/R (ie. birdcage) coil, the TORO approach provides improved signal in the region of the lung, which can be corrected by post-processing based on the simulation sensitivity profile of the coil.

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