Hyperpolarized $^{83}$Kr Imaging on a Clinical 3 T System

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Target Audience Researchers working with hyperpolarized gasses and lungs/respiratory disease.

Purpose Respiratory diseases have become one of the leading causes of hospitalizations, a rising cause of death, carry high economic impacts and one person in seven is currently affected by lung disease in the UK. The need to obtain sensitive, non-invasive information for diagnosis is therefore vital for improved healthcare, for reducing costs and for evaluating treatment efficacy. For this, MRI is an ideal modality, as it is non-invasive, there are no exposure limits and no long-term side effects.

The limitations of $^1$H MRI in the respiratory system are in the need for high tissue or fluid density to obtain high-resolution imaging. Therefore imaging the respiratory system with MRI requires a novel approach. The technological advances made at the physics – biomedical sciences interface with hyperpolarized (hp) gases promise to become the most significant advance in pulmonary diagnostics in decades.

Current research in the field of lung MRI has focused on two isotopes, $^3$He and $^{129}$Xe. These isotopes have produced high-resolution images, oxygen distribution mapping, and gas perfusion information. Here a different class of isotope, a quadrupolar isotope (spin I > 1/2), has been used which has shown sensitivity to changes in the environment being probed and therefore provides a different contrast mechanism. The isotope $^{83}$Kr has the potential to become a new contrast agent for respiratory MRI where changes such as inflammation, lung surfactant concentration, and alveolar shape could be monitored as important pathologies for lung disease.

A platform for ex-vivo animal lung imaging with hp noble gas isotope $^{83}$Kr is being developed. An $^{83}$Kr coil suitable for phantom imaging on a 3T MRI system has been built and assessed using a phantom to evaluate the feasibility of lung imaging using hp $^{83}$Kr.

**Methods** The coil, shown in Figure 1, was constructed on a cylindrical former (diameter = 22 cm, length = 40 cm). The coil design was a transmit/receive saddle-coil, a well-established volume coil design for use at 4.8 MHz (the resonant frequency of $^{83}$Kr at 3T). The coil was resonant at 4.877 MHz, had an impedance of Z = 40 – 12 Ω and a quality factor of Q = 2400. The phantom consisted of an acrylic cylinder (diameter = 20 cm, length = 5 cm) with two access ports. One port provided the inlet for the hp $^{83}$Kr. The second port provided vacuum prior to the introduction of the hp $^{83}$Kr (this port was closed when the hp $^{83}$Kr was introduced to the phantom). Scanning was performed on a Philips multi-nuclear 3T Achieva system (Philips Healthcare, Best, The Netherlands). Experiments included spectroscopy sequences to confirm the detection of $^{83}$Kr, FFE imaging and multiple-dynamic FFE imaging for $^1$H imaging. Hp $^{83}$Kr was produced via stopped flow spin-exchange optical pumping (SEOP) with a 100 W diode array laser (QPC Lasers) line-narrowed to 0.5 nm at the Rb D1 transition of 794.7 nm. The SEOP cell contained 1 g of Rb and the krypton mixture of 25 % krypton, 10 % nitrogen, 65% helium. A diagram of SEOP system is provided in Figure 2.

**Results** A spectrum obtained from the $^{83}$Kr is presented in Figure 3, and an axial image of the phantom is presented in Figure 4. Both clearly demonstrate the feasibility of detecting $^{83}$Kr on the 3 T system. The plot of signal intensity versus time (Figure 5) yields a $T_1$ of 48 s when fitted using equation 1 from Stupic et al. which accounts for polarization destruction from the RF pulse.

**Discussion** Detection of $^{83}$Kr images has been demonstrated using a clinically available MRI system both through spectroscopy and imaging. The $T_1$ time of 48 s allows for short term hp $^{83}$Kr storage at this field strength. The $T_1$ in lungs will be significantly shortened.

**Conclusion** Initial experiments with hp $^{83}$Kr show much potential for future imaging applications. The described setup allows for future measurements with porcine lungs that will provide a more realistic estimate of the $^{83}$Kr relaxation behaviour in humans.

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