Imaging of Dissolved-phase Hyperpolarized Xenon-129 in Human Kidneys

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Target audience: Imaging scientists and clinicians interested in applications of hyperpolarized contrast media.

Introduction & Purpose: Substantial progress has been made in recent years with imaging dissolved-phase hyperpolarized 129Xe in the human lung[1-3]. Early studies in animals demonstrated that inhaled 129Xe could also be detected, in dissolved form, in several other organs including the heart, brain and kidneys[4]. With recent advances in the volume and polarization that can be achieved for hyperpolarized 129Xe, it may be worthwhile to revisit imaging of dissolved-phase 129Xe outside of the lung. The purpose of this work was to determine if 129Xe can be detected in human abdominal organs, such as the kidneys.

Methods: Imaging was performed at 1.5T (Avanto, Siemens) in two healthy subjects (M, 27 yo; F, 29 yo) using a flexible chest RF coil (Clinical MR Solutions), which was positioned so that the superior end of the coil was over the bases of the lung or the kidneys. Enriched xenon gas (87% Xe129) was polarized by collisional spin exchange with an optically-pumped rubidium vapor using a prototype commercial system (XeBox-E10, Xemed LLC). Each subject inhaled a gas mixture containing 1-L of hyperpolarized 129Xe, polarized to 30-40%, and medical-grade nitrogen for a total volume equaling one-third of the subject's forced vital capacity as determined by spirometry on the day of imaging. All experiments were performed under a Physician's IND for imaging with hyperpolarized 129Xe using a protocol approved by our institutional review board. Informed consent was obtained in all cases.

Following inhalation of the 129Xe gas, coronal 2D projection dissolved-phase 129Xe images were acquired during a breath hold using either a spiral spoiled gradient-echo (TR/TE 600/0.7 ms; flip angle 30°; 10 interleaves @ 4.1 ms each; in-plane resolution 9x9 mm^2) or Cartesian balanced steady-state free precession (TrueFISP, TR/TE 5.56/2.74 ms; flip angle 20°; 40 phase-encoding lines; in-plane resolution 9x9 mm^2) pulse sequence. Both sequences used an RF pulse (1280 μs) designed to provide negligible excitation of gas-phase 129Xe when applied at 208 ppm above the gas-phase frequency.

Results & Discussion: Dissolved-phase 129Xe was seen in the kidneys of both subjects and for both pulse-sequence types. The SNR was substantially higher with the TrueFISP acquisition (SNR ~15). A linear structure, consistent with the position of the descending aorta, was seen passing between the kidneys in the spiral images.

The dissolved-phase 129Xe image obtained from subject 2 using TrueFISP is shown in Fig. 1a, next to a corresponding proton image in Fig. 1b. Dissolved 129Xe was seen in the bases of the lungs (red arrows) and the kidneys (yellow arrows). No uptake was seen in the liver, and little to no uptake was seen in the spleen. Figure 1c shows a spiral acquisition in subject 2 wherein the coil position was inferior to that for Fig. 1a. The bottom portions of the kidneys are seen (yellow arrows), along with a thick linear structure (white arrows) that passes between the kidneys and bifurcates just below the kidneys (Fig. 1c), at the same location as seen for the aorta in proton images (not shown). The position and general form of the structure is consistent with the descending aorta bifurcating into the left and right common iliac arteries; however, it appears far wider than these vessels. Assuming this structure is the descending aorta, a possible explanation for its appearance is that there are sizable signal contributions from both the red blood cell and plasma resonances (~20 ppm chemical shift difference; 350 Hz at 1.5T), which would cause substantial blurring in a spiral acquisition using 4.1 ms interleaves.

Conclusions: Dissolved-phase 129Xe images of the human kidneys have been demonstrated. Substantial improvements in image quality are anticipated through use of an RF coil sized appropriately for the kidneys, and acquisitions specifically optimized for the signal dynamics and relaxation characteristics of the kidneys. These results may be of interest for kidney perfusion imaging. In addition, if multiple 129Xe resonances can be detected in the kidneys, analogous to the lungs, dissolved-phase 129Xe imaging may offer additional interesting information on kidney function and disease.

References: **1.** Cleveland ZI et al. PLoS ONE 2010; 5:e12192. **2.** Mugler JP III et al. Proc Natl Acad Sci U S A 2010; 107:21707-21712. **3.** Qing K et al. J Magn Reson Imaging 2014; 39:346–359. **4.** Swanson SD et al. Magn Reson Med 1999; 42:1137-1145.

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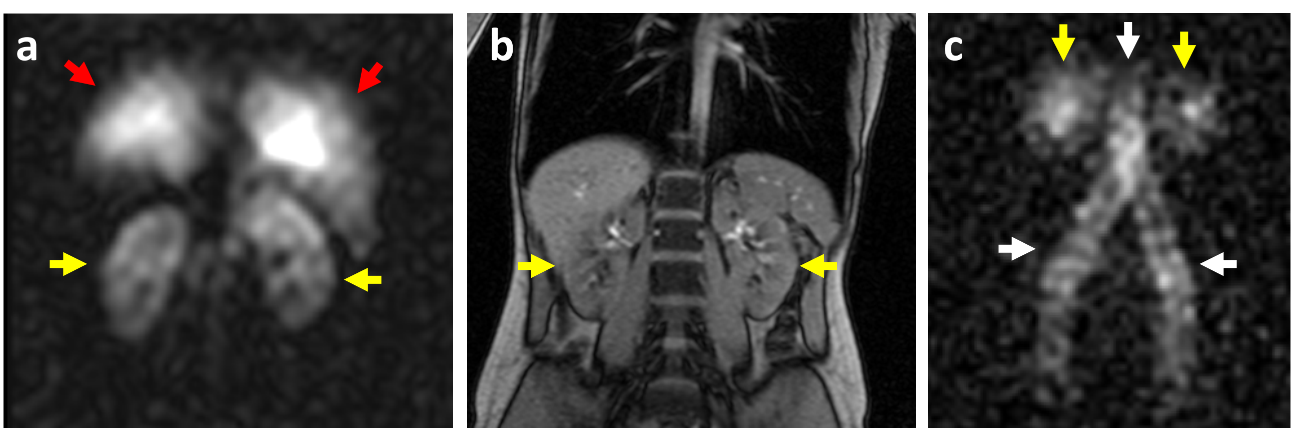

Figure 1. (**a**) Coronal projection dissolved-phase 129Xe image (TrueFISP) showing the bases of the lungs (red arrows) and the kidneys (yellow arrows). (**b**) Coronal proton gradient-echo image corresponding to (a). (**c**) Coronal projection dissolved-phase 129Xe image (spiral) showing the lower portions of the kidneys (yellow arrows) and a linear structure (white arrows) consistent with the position of the descending aorta, bifurcating into the common iliac arteries.