# Motion-corrected $pO_2$ mapping in human lungs using hyperpolarized Xe-129 MRI

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**Background:** T1-weighted imaging of inhaled hyperpolarized gas can be used to quantify the partial pressure of oxygen ($pO_2$) in lung airspaces. A short-breath-hold implementation of the $pO_2$-mapping technique, using hyperpolarized $^3$He, was shown to accurately depict known $pO_2$ variations in phantom experiments, and yielded physiologically plausible $pO_2$ maps in human lungs [1]. Although most $pO_2$ mapping studies to date have used $^3$He, wider application of this promising technique would require the use of $^{129}$Xe [2].

One obstacle to robust implementation of this technique is subject motion, including relaxation of the diaphragm during the breath hold. Since the $pO_2$ calculation involves the pixel-by-pixel subtraction of images obtained several seconds apart, the resulting maps are highly susceptible to bulk motion of the inhaled gas during the acquisition.

**Purpose:** To demonstrate the feasibility of $pO_2$ mapping using hyperpolarized $^{129}$Xe in healthy and diseased human subjects, and to explore the potential for using an image registration algorithm to compensate for subject motion during the breath-hold acquisition.

**Methods:** Hyperpolarized $^{129}$Xe imaging was performed in ten subjects (5 healthy non-smokers, 1 healthy smoker, 1 COPD, 1 cystic fibrosis, and 2 sickle cell disease) using a 1.5T commercial scanner, flexible chest RF coil, and commercial prototype $^{129}$Xe polarizer. In each subject, a $pO_2$ map (48×64 matrix, 6 mm resolution) was acquired at breath hold following inhalation of a ~1 L mixture containing 135 ml $O_2$, 350 ml room air, and approximately 500 ml hyperpolarized $^{129}$Xe (total oxygen concentration ~21%). A short-breath-hold implementation (total breath hold ~10 sec) of a standard $pO_2$-mapping pulse sequence was used [3], in which a total of 3 images were acquired with an oxygen-sensitization time of 5 seconds between the 2nd and 3rd images. All images were acquired as coronal projections using a non-selective RF excitation pulse, although a thinner section was isolated in some of the scans, by using slice-selective pulses to destroy the hyperpolarized magnetization on either side of a 60-mm coronal slice immediately before executing the $pO_2$-mapping pulse sequence.

Motion correction was implemented by applying a locally affine, globally smooth warping algorithm to generate co-registered versions of all three images [4]. For comparison, two flip-angle-compensated $pO_2$ maps were generated for each scan (from the warped and un-warped image sets) and mean $pO_2$ values were calculated from the simple average of the $pO_2$ pixel values.

**Results:** Fig.1 shows the mean $pO_2$ values for each subject. For most subjects the $pO_2$ difference was only a few percent between the original and motion-corrected $pO_2$ maps. In a few subjects, the mean $pO_2$ value was much lower on the motion-corrected maps, primarily due to the reduction of physiologically impossible $pO_2$ values near the diaphragm. Fig.2 shows imaging results for the case of (a) large motion correction, (b) smaller but significant motion, and (c) no obvious motion. Motion correction did not eliminate anomalous $pO_2$ values near the heart, as seen in Fig. 2b. The average $pO_2$ among normal subjects was 113 mm Hg, whereas the average $pO_2$ among diseased subjects was slightly higher (118 mm Hg).

**Conclusions:** Lung $pO_2$ mapping with hyperpolarized $^{129}$Xe appears entirely feasible in humans, and yields physiologically plausible $pO_2$ maps that are very similar in character to previously reported $^3$He results [1]. Although mean $pO_2$ values were slightly higher than previously measured using $^3$He, the measured values were not as large as previously reported results for hyperpolarized $^{129}$Xe [2].

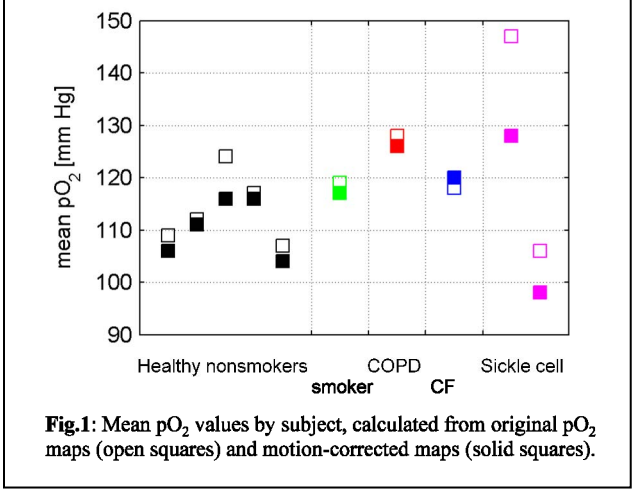


**Fig.1**: Mean $pO_2$ values by subject, calculated from original $pO_2$ maps (open squares) and motion-corrected maps (solid squares).

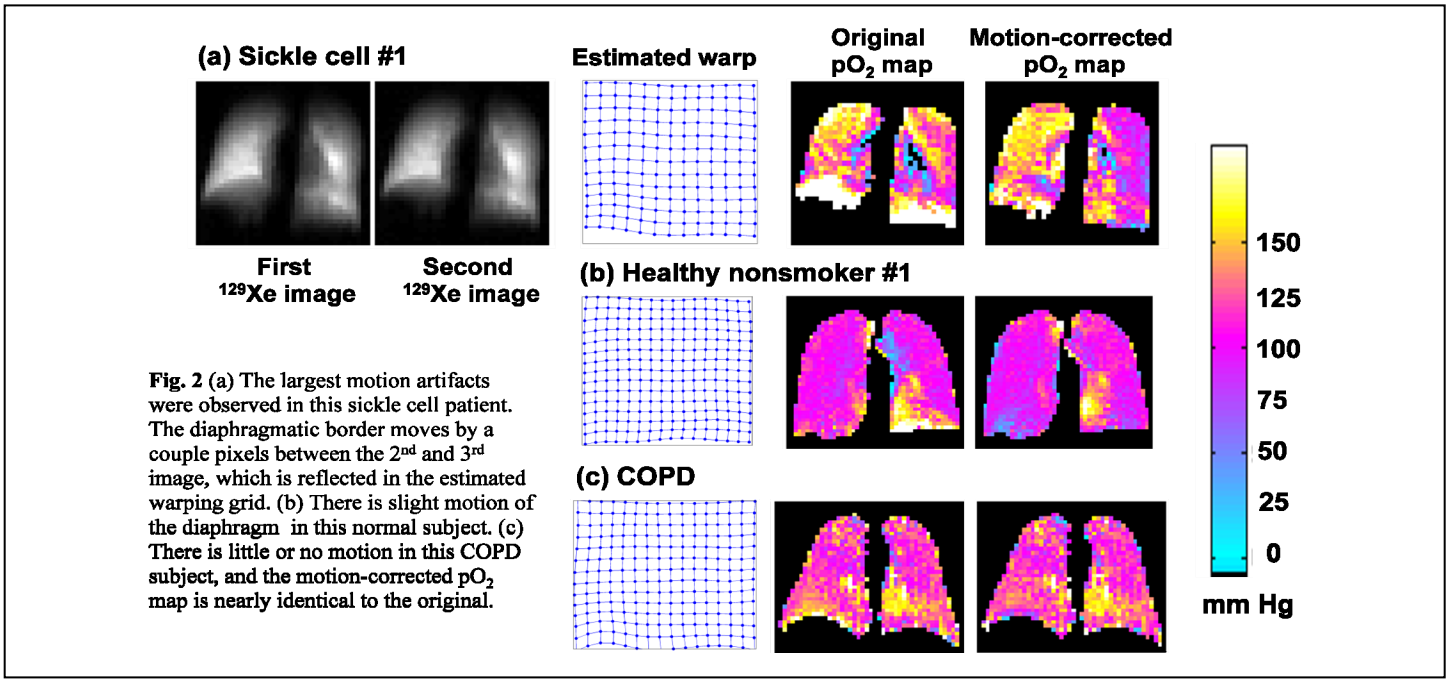


**Fig. 2** (a) The largest motion artifacts were observed in this sickle cell patient. The diaphragmatic border moves by a couple pixels between the 2nd and 3rd image, which is reflected in the estimated warping grid. (b) There is slight motion of the diaphragm in this normal subject. (c) There is little or no motion in this COPD subject, and the motion-corrected $pO_2$ map is nearly identical to the original.

**References: [1]** G.W. Miller et al., *Magn Reson Med* 2009, in press. **[2]** S. Patz et al., *Eur J Radiology* 2007; 64:335. **[3]** M.C. Fischer et al., *Magn Reson Med* 2004; 52:766. **[4]** S. Periaswamy and H. Farid, *IEEE Trans Med Imaging* 2003; 22:865.

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