Detection of Pulmonary Emboli by Hyperpolarized Carbon-13 in Pig Model

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Introduction: Pulmonary embolism is a devastating disease associated with significant morbidities and mortalities. Non-specific symptoms make the diagnosis difficult; the diagnosis is usually confirmed with an imaging study such as nuclear medicine ventilation perfusion scans, pulmonary angiography, or computed tomography. While these methods have significantly impacted detection and treatment of pulmonary emboli, they suffer from important intrinsic limitations; in particular, these studies are often contraindicated in tracheotomized patients and patients with poor kidney function. These constraints highlight the need for new imaging modalities readily applicable to this subpopulation. Recently there has been considerable interest in the development of water-soluble hyperpolarized ^{13}C based MRI contrast agents [1]. MRI methods based on derivatives of these novel contrast agents may lead to a new form of MRI angiography free from the restrictions listed above and thus applicable to the patient subpopulation of interest. We present our findings for the detection of model pulmonary emboli using the HP contrast agent 2-hydorxyelthyl acrylate.

Method: Yorkshire pigs were induced, intubated, paralyzed, and maintained on isoflurane anesthesia. Vital signs were monitored during the procedure. Ten millimeter balloon catheters were placed in the right inferior pulmonary arteries under fluoroscopic guidance. After angiographic confirmation of the balloon catheter's location the balloon was deflated and the pigs were placed in a birdcage coil tuned to the ^{13}C frequency. The pig and coil were then positioned in a 1.5-T whole-body imager (Sonata, Siemens). The lungs were localized in space using a series of proton images. HP MRI angiography was then performed using 5 ml of 300 mM solution of HP 2-hydroxyethyl acrylate injected at a rate of 3 ml per second. Net polarization: 11%. The hyperpolarized ^{13}C solution was prepared via the parahydrogen induced polarization technique using a prototype polarizer (GE Healthcare, Chalfont St. Giles, United Kingdom). MRI imaging began thirteen seconds after injection of the HP 2-hydroxyethyl acrylate using a tFISP pulse sequence with the following imaging parameters: TR/TE, 4.6/2.3 msec: FOV: 32x32 cm; matrix size 128x128, slice thickness was 2.5 cm. The experiments were repeated with the balloon inflated and deflated.

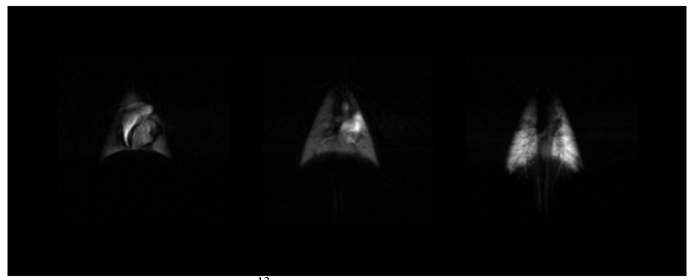

Figure 1 Three coronal HP ^{13}C MRI angiograms depicting pulmonary blood flow in the balloon deflated condition. Left, middle, and right images represent anterior, middle, and posterior positions respectively. The pulmonary vasculature, inferior vena cava, and perfused lung parenchyma are clearly depicted in the images, where as air filled structures such as the bronchial tree and surrounding tissues not supplied by the pulmonary artery appear devoid of signal. Note the characteristic high signal to noise ratios of the HP ^{13}C images, and the low background signal, suggesting that HP ^{13}C techniques may be useful to measuring pulmonary perfusion.

Results and Discussion: Figure 1 depicts sample HP MRI ^{13}C pulmonary angiograms obtained in a normal pig. Note the high signal to noise ratios obtained using the HP ^{13}C technique and the nearly absent background signal, suggesting that this technique may lend itself to absolute measures of pulmonary perfusion. In Figure 2 we show pulmonary angiograms taken after a balloon in the right inferior pulmonary artery was inflated. A large perfusion defect is clearly depicted in the right inferior lobe confirming the pulmonary perfusion in the right inferior lung lobe is severely restricted. High signal to noise ratios are noted in the central and great arterial vasculature suggesting that sufficient polarization is retained by the HP contrast agent after passing through the lung to allow for arterial angiography after venous injection of the contrast agent.

Conclusion: HP MRI ^{13}C angiography of the lungs is feasible and can be used to detect perfusion abnormalities, such as those encountered during pulmonary embolism. This technique provides images with high signal to noise and low background contamination suggesting that HP ^{13}C methods will be amenable to measuring regional pulmonary perfusion. Furthermore, the technique provides high-resolution images in short time periods. These results indicate that HP MRI ^{13}C angiography may lead to a viable method for detecting and diagnosing pulmonary embolisms in critical ill patients with poor kidney function who are poor candidates for traditional diagnostic methods such as pulmonary angiogram and computed tomographic angiography.

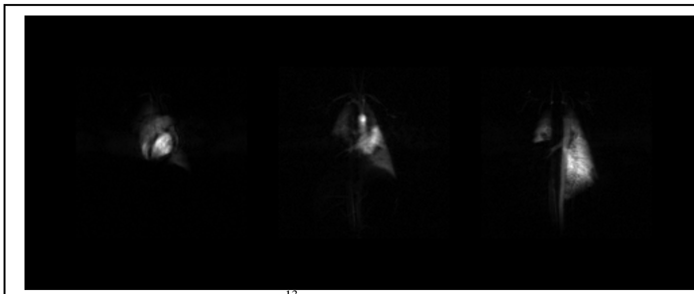

Figure 2 Three coronal HP ^{13}C MRI pulmonary angiograms taken after a balloon catheter situated in the right inferior pulmonary artery was inflated. This simulates a moderately large pulmonary embolism of right inferior pulmonary artery vascular distribution. As above, left, middle, and right images represent anterior, middle, and posterior positions respectively. A large perfusion defect is clearly depicted in the right lower lobe of the lung. Contrast agent leaving the left ventricle can be seen filling the arterial circulation in the middle and posterior images.

References: [1] Svensson J, Månsson S, Johansson E, Petersson JS, Olsson LE, Magn. Res. Med. 50(2): 256 – 262 (2003)