Impact of a Simulated Pulmonary Embolism in a Rabbit Model as Detected by XTC MRI

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Introduction: Previous studies have demonstrated the feasibility of indirectly detecting a pulmonary embolism (PE) using hyperpolarized helium-3 (HHe-3) MRI by tracing the gas-signal depletion following the injection of a paramagnetic contrast agent (1), quantifying the regional oxygen depletion rate in the lung (2) or by combining HHe-3 ventilation images with proton perfusion measurements (3). Using Xenon polarization Transfer Contrast (XTC) MRI (4-6), hyperpolarized xenon-129 (HXe-129) may expand these capabilities by directly combining information about lung ventilation and regional blood volume in a single 4s breath-hold acquisition. In this work we investigated whether XTC MRI can detect changes in pulmonary blood volume, and whether this method is sensitive enough to detect the impact of a PE using a previously described PE rabbit model (3).

Methods: Experiments were performed on a 1.5-T commercial whole-body imager (Sonata, Siemens Medical Solutions, Malvern, PA) using a custom-made transmit-receive birdcage RF coil (IGC Medical Advances, Milwaukee, WI). The two imaging segments of the XTC acquisition were asymmetric FLASH sequences (75% of *k*-space sampled) with excitation flip angles of 5.1° and 14.3°. The following sequence parameters were used: non-selective excitation with a 160μs Gaussian RF pulse; matrix size 40×64; TR/TE 13.5/7.0 ms; FOV 160 mm; receiver bandwidth 80 Hz/pixel. The two FLASH image acquisitions were separated by a series of 22 contrast-generating 180°/-180° RF pulse pairs with an inter-pulse delay of 40 ms applied at the dissolved-phase resonance frequency of 202 ppm for the XTC experiment or at -202ppm for the control experiment. The chosen 40-ms delay time makes the XTC MRI experiments sensitive to changes in the volume of the dissolved-phase compartments involved in short-range gas exchange. Six New Zealand rabbits (4.2-5.2 kg) had a non-detachable occlusion balloon catheter placed in their left pulmonary artery under fluoroscopic guidance. This balloon permitted full occlusion of the left pulmonary artery, blocking the blood supply to the associated lung (Fig. 1a). Data was acquired with the balloon initially deflated. The studies were repeated after the balloon had been inflated. The animals were ventilated with 30cc of isotopically enriched (85% ^{129}Xe) xenon gas, polarized to approximately 10-15% via spin exchange with an optically pumped rubidium vapor (Model IGI 9600Xe Xenon Polarizer, MITI, Durham, NC). Once the HXe-129 studies had been concluded and while the left pulmonary artery was still occluded, each animal was also scanned using a 3D contrast-enhanced MRA (CE-MRA) sequence following an injection of 3cc of a gadolinium chelate. The protocol was approved by our Institutional Animal Care and Use Committee.

Results: Figure 1 depicts the lack of blood flow in the occluded left lung (Fig. 1a), the gas-phase depolarization maps from the rabbit lung before (Fig. 1b) and after (Fig. 1c) balloon inflation, and the relative changes in depolarization (Fig. 1d). Shortly after balloon inflation, large changes in the gas-phase depolarization maps became apparent in all animals, although the individual animals exhibited considerable variability in their response to the simulated PE in their left lung. The following general observations were made: a) regional depolarization decreases of 20% or more in the left lower lobe (4 out of 6 animals); b) regional depolarization increases of 20% or more in the left upper lobe (5 out of 6); c) regional depolarization decreases of 20% or more in the right lung (3 out of 6); and d) regional depolarization increases of 20% or more in (other regions of) the right lung (6 out of 6).

Conclusion: While the repeatability of the XTC MRI technique is very high, variability is potentially introduced by the quality of the balloon seal, the exact level of lung inflation after the manual administration of HXe-129, as well as changes in the cardiac output of the individual rabbits. The observed changes in the depolarization maps are most likely due to a redistribution of the pulmonary blood volume after the occlusion of the left pulmonary artery, which led to regional drainage (predominantly in the left lung) and blood pooling due to shunting (predominantly in the right lung and the lower lobes). Thus, our results demonstrate that XTC MRI is not only highly sensitive to regional changes in lung tissue volume (5,6) but also to a redistribution of the pulmonary blood volume and, indirectly, lung perfusion.

References

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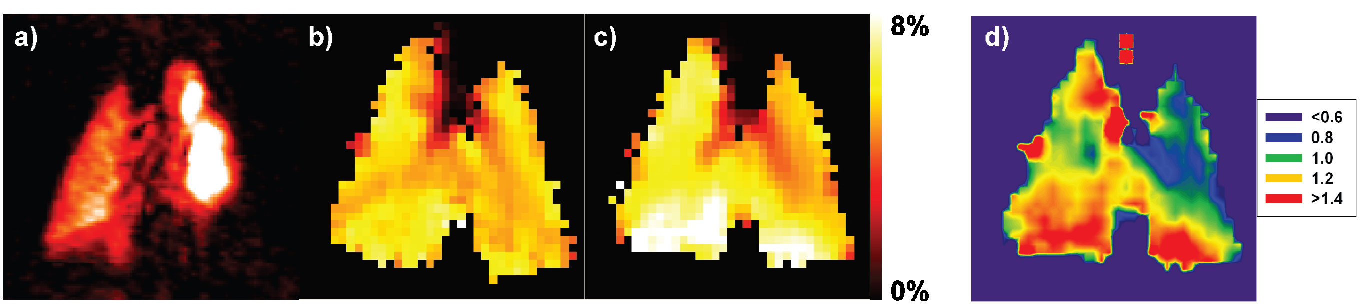

Figure 1. (**a**) CE-MRA image of the lung illustrating the lack of perfusion in the left lung (the bright region is the heart). Gas-phase depolarization maps (coronal projection) before (**b**) and during (**c**) inflation of the balloon that occluded the left pulmonary artery and simulated a pulmonary embolism. The relative depolarization changes between the depolarization maps are depicted in (**d**).