Imaging Stroke with Hyperpolarized ^{129}Xe MRI

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Introduction

Stroke is the third leading cause of death in developed countries. Although conventional proton MRI [1] has been routinely used to image stroke, hyperpolarized (HP) ^{129}Xe MRI may offer advantages in imaging stroke due to xenon's high lipid solubility and absence of background signal in biological tissue. Because xenon is delivered to the brain through the blood, a signal void is expected to occur in areas of decreased cerebral blood flow (CBF). Here we demonstrate the capability of HP ^{129}Xe MRI to detect with anatomical specificity, areas of decreased CBF induced by middle cerebral artery occlusion (MCAO). These findings show the great utility of HP ^{129}Xe MRI for imaging stroke and suggest that HP ^{129}Xe MRI may serve as a complementary tool to proton MRI for studying the structure and function of the brain.

Materials and Methods

Male Sprague-Dawley rats (n=2) weighing 175-200 g were anesthetized with isoflurane (5% for induction, 2% for surgery, 1.2% for maintenance) in room air. Following endotracheal intubation with a 14-gauge, 3.5 cm catheter, and animals were placed in the magnet and the catheter was connected to an animal respirator, which was interfaced to an MR compatible gas delivery system controlled by a computer. Animals were ventilated with room air, their body temperature was maintained at 37.0±0.5°C using a feedback regulated heating pad. The animal's blood oxygenation and heart rate were monitored throughout the experiment. All MR measurements from the rat brain were carried out on a Bruker Biospec 4.7 T MRI system using a dual-tuned surface coil tuned to the ^{1}H and ^{129}Xe resonance frequencies (200 and 55.4 MHz, respectively). The proton apparent diffusion coefficient (ADC) and HP ^{129}Xe chemical shift imaging (CSI) were performed up to 90 minutes after MCAO. Two axial spin-echo ^{1}H ADC maps were separately acquired over 8.5 minutes with matrix=128×128, recovery time=2 sec, echo time=35.2 ms, Δ=24 ms, δ=4.75 ms, b=6.070 and 1366.159 s/mm^2, field of view=2.5×2.5 cm, a 2.5 mm thickness slice, and 1 average. The rats were ventilated with alternate breaths of air (2 sec) and HP ^{129}Xe gas (2 sec), and the HP ^{129}Xe CSI was acquired over 4.25 minutes with matrix=16×16, recovery time=1 sec, field of view=2.5×2.5 cm, slice thickness=5 mm with the slice centered at the center of the ADC slice, and 1 average. ^{129}Xe was polarized to 10% using a gas flow-through polarization system (IGI.XE.2000, GE Healthcare). In addition, HP ^{129}Xe CSI was performed on a normal rat (without MCAO) in order to compare it to the one with MCAO.

Results and Discussion

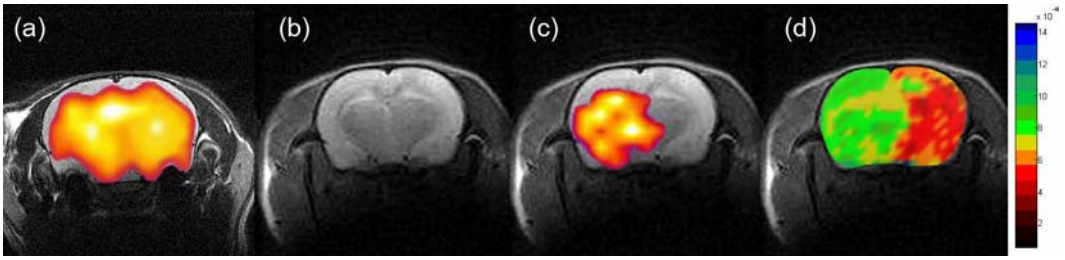

Figure 1. HP ^{129}Xe CSI image (a) from a normal rat without MCAO. The proton reference image (b), HP ^{129}Xe CSI image (c) of animal with right MCAO, and the proton ADC map image (d) from the same stroke rat. The right side color bar is only used for the ADC map image (d).

Figure 1(a) shows a HP ^{129}Xe CSI image from a normal rat brain, in which the HP ^{129}Xe signal from both hemispheres can be clearly observed. Figures 1(b)-(d) were acquired from an animal receiving a right MCAO. Figure 1(b) is the proton reference image, and figure 1(c) is the HP ^{129}Xe CSI image showing a signal void in the right hemisphere coinciding with the area of restricted blood flow. The HP ^{129}Xe signal void in the right hemisphere is believed to be due to a combination of the lower CBF and the faster relaxation resulting from the lower blood oxygenation which occurs in MCAO [2-3]. Figure 1(d) shows a proton ADC map image of the same rat stroke model at 60 minutes after right MCAO. Following MCAO, the ADC in large parts of the ipsilesional (right) MCA territory was reduced below the critical threshold of 5.3×10^{-4} mm^2/s for ischemia [1]. The ischemic brain tissue shown by the ADC map image is consistent with the areas of reduced CBF as imaged with the HP ^{129}Xe.

Conclusion

We show that HP ^{129}Xe MRI is able to detect with anatomical specificity an area of decreased CBF induced by MCAO. These results were compared with a method of determining the areas of critically ischemic tissue, namely, proton ADC mapping. These results demonstrate the feasibility of detecting stroke using HP ^{129}Xe MRI. The additional sensitivity of HP ^{129}Xe to blood oxygenation and chemical environments [4-5], suggest it may find great utility in many clinical applications in the future.

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Reference

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