Functional Brain Imaging Using Hyperpolarized ^{129}Xe

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Introduction

Hyperpolarized noble gas MRI is a relatively new and innovative imaging method that is yielding information of structure and function previously undetectable with conventional MRI. Hyperpolarized xenon (HP ^{129}Xe) MRI is especially promising for studies of brain function and pathology, due to its high lipid solubility and sensitivity to chemical environment. In this study we demonstrate, for the first time, its use as a method for functional imaging in the brain.

Methodology

Imaging was performed on a 4.7 T/ 33 cm bore Bruker Biospec Advance system magnet controlled by a console running ParaVision software. A proton birdcage coil was used in combination with a ^{129}Xe surface coil to transmit and receive signals at both the proton (200 MHz) and xenon (55.35 MHz) frequencies. Male Sprague-Dawley rats weighing between 200-250 g were initially anesthetized by a 1.5 ml/kg i.p. injection of a ketamine:xylazine mixture (57:8.5 mg/ml), and a tracheostomy was performed whereby the airway was catheterized with a 14-gauge, 3.5 cm catheter. The animal was placed on a modified ventilator and ventilated with 97% O_2 and 3% isoflorane so that anesthesia was maintained throughout the imaging proceedure. Breathing rate was 40 breaths per min with a 400 ms inspiration period, a 250 ms breath-hold period, and a 850 ms expiration period and an inter-breath interval of 1500 ms. A tidal volume of 3 ml was supplied for each breath. After the acquisition of a coronal proton slice image, HP ^{129}Xe was administed using alternate breaths of ^{129}Xe and the O_2/isoflorane mixture, over a four minute period during which a baseline ^{129}Xe chemical shift image (CSI) was acquired. Next, functional brain haemodynamic changes were evoked pharmacologically, by the administration of 5% CO_2. The animal was ventilated with a mixture of O_2 : CO_2 : isoflorane in a ratio of (92% : 5% : 3%) over a 5 minute period and a second CSI was acquired. Images acquired before and after administration of CO_2 were digitally subtracted to produce difference images that reflect changes in ^{129}Xe distribution caused by CO_2.

Results and Discussion

Functional brain haemodynamic changes caused by the administration of CO_2 could be clearly detected by HP ^{129}Xe in the rat brain (Figure 1). For anatomical reference, a high resolution coronal proton image was taken of the rat head, so that the entire brain with olfactory bulbs and cerebellum could be easily visualized (Figure 1a). A HP ^{129}Xe CSI image revealed unrestricted distribution of ^{129}Xe throughout the brain, although the signal intensity varied across different regions of the brain (Figure 1b). The ^{129}Xe signal clearly originated from within the brain tissue, consistant with previous reports [1]. Administration of 5% CO_2 caused a differential distribution of HP ^{129}Xe in the brain, which was revealed upon subtracton of the pre- CO_2 from the post- CO_2 image (Figure 1c). The difference in ^{129}Xe signal distribution is likely to reflect areas of increased cerebral blood flow resulting from CO_2 induced vasodilation [2]. The two priciple changes associated with increased neuronal activity are increased blood flow and increased O_2 tissue content. Because HP ^{129}Xe is sensitive to both increased blood flow and O_2 content, it is uniquely suited for further development as an indicator of functional brain activity.

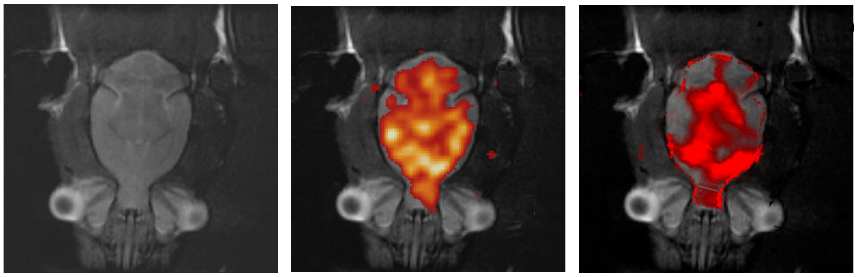

Figure 1. (a) Proton image of 10 mm coronal slice through the rat brain acquired with RARE sequence, TE=30 ms, TR=2000 ms, av=2. (**b**) falsecolor overlay of HP ^{129}Xe CSI image acquired with a 2D CSI sequence using 16 phase encoding steps in two dimensions, a phase gradient duration of 500 us, a flip angle of 5°, a TR of 100 ms, a FOV of 2.5 cm, and a slice thickness of 10 mm. K-space data was zero-filled to yield a linear reconstructed image of 32 x 32 pixels. Proton image in (a) shown with overlay of HP ^{129}Xe MRI for anatomical registration. (c) falsecolor CSI difference image of HP ^{129}Xe obtained after the administration of 5% CO^2 for 5 minutes.

Conclusion

Changes in cerebral haemodynamics in the rat brain were imaged with HP ^{129}Xe, using chemical shift imaging. To our knowledge, this is the first report of functional brain imaging using HP ^{129}Xe MRI.

References

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Acknowledgments

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