Comparison of 129Xe Spectra from Intact and ECA/PPA Obstructed Rat Head

Y. Kondoh1, A. Wakai2, K. Nakamura2, J. Kershaw2, D. Wright2, I. Kanno1

1Akita Research Institute for Brain and Blood Vessels, Akita-shi, Japan, 2Akita Industry Promotion Foundation (AIPF), Akita-shi, Japan

Introduction

The properties of xenon in a biological environment and the development of techniques to hyperpolarize inert gases have made 129Xe a potential MR probe of brain physiology and function. For this to become reality it is first necessary to understand the forms that xenon adopts in brain. Published *in vivo* spectra of 129Xe in rat head show several peaks that have been attributed to the chemical shift of xenon in blood, fat, lipid, or white and gray matter (eg. [1-6]). In particular, peaks at 194.5 ppm and 199 ppm have both been attributed to brain tissue. However, there remains some discord as to the origin of each peak. In order to resolve this issue in our laboratory, we compared spectra obtained from the heads of normal rats with spectra taken from the heads of rats that had a ligation of the extra carotid (ECA) and pterygopalatine arteries (PPA), the major feeding vessels of non-brain tissue in the rat head.

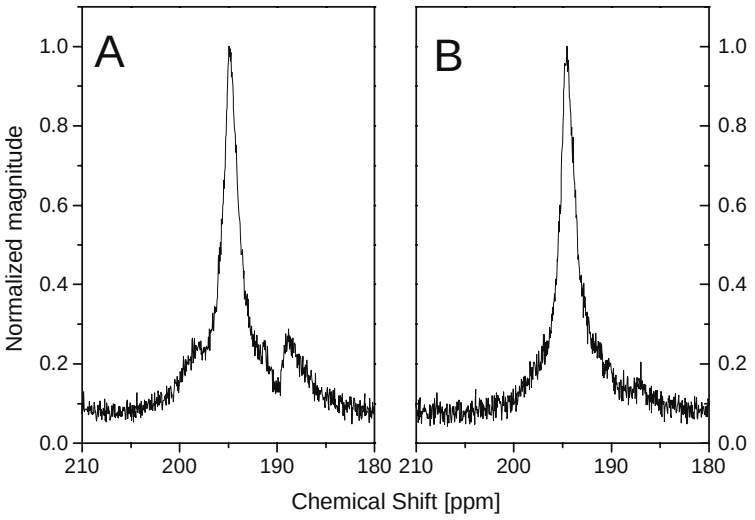
Methods

Male Sprague-Dawley rats (320-460g, n=8; 3 obstructed rats and 5 normal rats) were anaesthetised with halothane. An endotracheal tube (8Fr, Atom multipurpose tube) was inserted into the trachea followed by a thinner tube (PE10) coaxially inserted so that hyperpolarized gas could be almost directly inhaled into the lungs from outside the magnet. For the obstructed rats, both sides of the carotid artery branches were exposed and the ECA and PPA were ligated. After preparation the rats were set in the magnet and the anaesthesia was maintained with 0.5-1% halothane or α-chloralose (20-40 mg/kg/h, i.v.).

MR measurements were performed on a 4.7 T Varian imaging spectrometer using a custom-made 3 cm surface coil dual-tuned to the proton and xenon resonances at 200.704 MHz and 55.516 MHz, respectively. Scout images and shimming were performed at the proton resonance at the beginning of each experiment. Spectra were acquired using a single hard-pulse sequence with a bandwidth of 30 kHz and the RF pulse centred at approximately 150 ppm from the gas peak.

Hyperpolarized 129Xe gas (enriched 129Xe 80% + N2 20%) with a polarisation of around 2-6% was produced in a homemade polariser. A 25cc volume of hyperpolarized gas was smoothly injected into the lungs of the animals over a period of 20-40 seconds and spectra were acquired 3-4 seconds after the injection finished. This protocol was repeated 4-23 times with the same acquisition parameters for each rat. The results were averaged across experiments and rats to obtain the final spectra for the two conditions. No smoothing was applied.

After completion of the experiment, a stain (Evans blue dissolved in saline) was injected into the rat through the tail vein to check whether the ECA/PPA obstruction was effective. The heads of the obstructed rats did not stain, confirming that Xe gas was not delivered to non-brain tissue.



Results

The averaged spectra (n=50) for the intact and obstructed rats are contained in Figure 1. Fig. 1A clearly shows a major peak at 194.5 ppm with three smaller peaks at approximately 188 ppm, 191 ppm and 197-8 ppm in the intact rats. For the ECA/PPA obstructed rats the major peak at 194.5 ppm persists while the amplitudes of the three smaller peaks have been greatly reduced (Fig. 1B). This confirms that the xenon signal originating from rat brain is overwhelmingly dominated by the single resonance at 194.5 ppm.

Discussion

The subpeaks do not completely disappear in the ECA/PPA obstructed rats. This may be because non-brain tissue is still being fed by collateral blood flow from an artery undisturbed by the ECA/PPA obstruction.

Considering the geometry of the surface coil, the smaller peaks observed in the normal rats may originate from xenon dissolved in muscle tissue on the upper part of the skull.

Other published work has found an additional large peak at 199 ppm that is attributed to xenon in brain tissue (eg. [1,5]). However, that work uses an intra-carotid injection of xenon mixed with a lipid emulsion. When inhalation is used to deliver the xenon, the peak at 199 ppm is not prominent (eg. [2,6]). The reason for this discrepancy remains to be solved.

The decay times of 129Xe from the intact and obstructed rat brains were found to be identical (data not shown).

References

[1] Duhamel et al, MRM 46:208-212 (2001); [2] Venkatesh et al, preprint (2002); [3] Peled et al, MRM 36:340-344 (1996); [4] Wilson et al, MRM 41:933-938 (1999); [5] Choquet et al, MRM 49:1014-1018 (2003); [6] Swanson et al, MRM 38:695-698 (1997).