SNR improvement of a $^{13}$C-cryo-coil in comparison with room-temperature coils

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Introduction

MRS studies typically require a high signal-to-noise ratio (SNR), especially for $^{13}$C-spectroscopy where the low natural abundance of $^{13}$C (1.1%) is a problem. Since the SNR depends on the third power of the Larmor frequency, the relative small frequency of $^{13}$C increases this limitation for $^{13}$C in comparison with $^1$H-MRS. There are methods to enhance the signal like polarization transfer. Another way is to lower the noise. Cryo-coils use the fact that there are two noise sources, which can directly be diminished. Noise arising from the coil itself and the preamplifier can greatly be lessened by lowering its operating temperature. Thus mainly the noise from the sample itself is left. We present in vivo and in vitro data from one of the first $^{13}$C-cryo-coils for mouse brain.

Methods

We compared a $^{13}$C-cryo-coil prototype for mouse brain imaging (Bruker, Ettlingen, Germany) with a standard surface coil from the same supplier (Fig 1a) and a home-built coil with an optimized geometry for mouse brain imaging (Fig 1b) on a 9.4 T horizontal bore animal scanner (Bruker, Ettlingen, Germany).

The $^{13}$C-cryo-coil consists of an anatomically-shaped $^{13}$C element and a $^1$H saddle coil for decoupling. Due to its geometry only small animals like mice can be scanned (Fig 1c). The $^{13}$C element as well as the narrow band preamplifier are encapsulated in an insulated vacuum chamber and are helium cooled to lower their operating temperature down to approximately 30K. To avoid injuries the contact area of the coil is heated. The standard surface coil consists of a double tuned flat single loop (20mm diameter) with manual tuning on both frequencies.

The home-built $^{13}$C transceiver surface coil (Fig. 1b) was constructed to approximate the cryo-coil’s geometrical design. It was build from 1mm thick silver wire insulated by heat shrinkable tubing on both frequencies. Another way is to lower the noise. Cryo-coils use the fact that there are two noise sources, which can directly be diminished. Noise arising from the coil itself and the preamplifier can greatly be lessened by lowering its operating temperature. Thus mainly the noise from the sample itself is left. We present in vivo and in vitro data from one of the first $^{13}$C-cryo-coils for mouse brain.

Discussion

Besides the noise reduction through the low temperature, the high SNR gain of the $^{13}$C-cryo-coil has several other reasons. We could determine that a factor 1.8 is owed to the optimized anatomically shaped geometry through building a coil with a comparable design. Another important factor is the optimized narrow bandwidth receiver chain that is connected to the cryo-probe, which also improves the SNR compared to the other coils which use the standard broad-band receiver. The SNR gain by these factors allow considerably shorter acquisition times and higher spatial resolution. Additionally, due to the low resistance the high quality factor Q of the coil allows the application of comparable short RF pulses and thus can increase the bandwidth of the signal excitation, which allows the acquisition of a wider range of resonances in a single experiment.