In vivo absolute quantification for mouse muscle metabolites using an inductively coupled synthetic signal injection method and newly developed 1H/31P dual tuned probe

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Introduction

We have developed a new MR absolute quantification method that injects an inductively coupled pseudo-signal during acquisition of real signal [1-3]. The coupling mechanism between an injector coil and the primary RF coil used for signal acquisition is magnetic induction, rather than broadcast radiation. Since the injector coil is fixed in position and orientation relative to the receive coil, inductive coupling between the two coils remains constant and independent of sample size or the location of other objects near the bore of the magnet. Therefore, all parameters downstream of the RF coil that affect quantification have equal affect on the pseudo-signal and the real signals. Any changes in these parameters, in particular coil loading and receiver gain, which might occur between subjects or in a single subject due to physiological perturbations, are transparent and have no effect on the quantification process. In this study, we have applied this method to determine ^{31}P metabolite content in mouse hind-limb muscles. To improve the signal-to-noise ratio, we developed a dual tuned ^{1}H/^{31}P mouse leg probe with injection coils incorporated for MRI/MRS measurements.

Methods

MRI/MRS data were acquired from 5 normal mice on a Bruker 4.7 T horizontal bore magnet equipped with a Varian INOVA spectrometer. A ^{1}H/^{31}P dual tuned volume coil was designed and fabricated for mouse leg muscle MRI/MRS as shown in Fig.1. The probe was composed of two sets of dual tuned ^{1}H/^{31}P solenoid coils: each mouse leg was inserted into each solenoid incorporated with an individual injector to introduce pseudo signals simultaneously or separately with the real signals arising from the tissue.

Phantom measurements were conducted to calibrate a pseudo-signal for our signal injection approach. We prepared the phantom with an inorganic phosphate (50 mM), sodium tripolyphosphate (10 mM) and phenyphosphoric acid (10 mM). *In vivo* ^{31}P measurements were performed on hind-limb muscle of both legs for each mouse as shown in Fig. 2C.

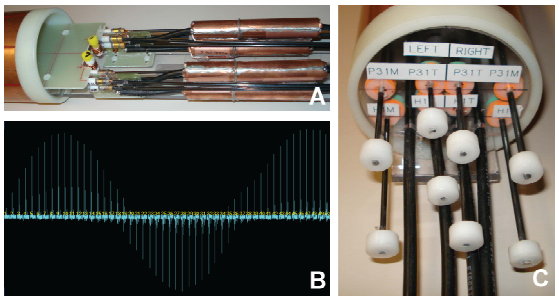

Figure 1. Dual tuned 1H/31P probe for two mouse legs *in vivo*. A. Two solenoid RF coils are shown with their tune/match networks and 1H/31P balans for all cables. B. RF homogeneity for 31P signal was examined to generate up-to 270 degree flip angles by varying pulse width (ranging from 10 to 250 μsec) with a constant RF power of 30 dB. C. An end view of the dual tuned 1H/31P probe showing 8 tuning rods for all variable capacitors.

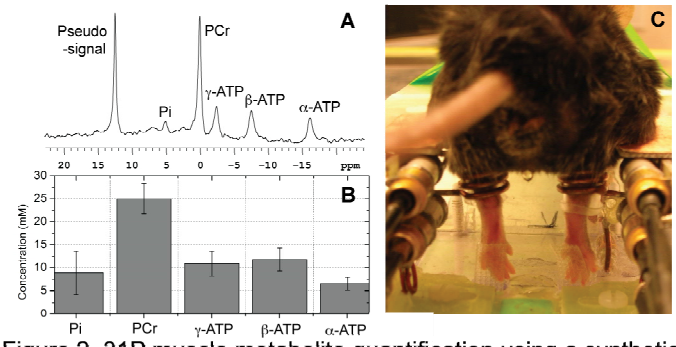

Figure 2. 31P muscle metabolite quantification using a synthetic signal injection method and a dual tuned 1H/31P probe equipped with injectors. A. *In vivo* 31P MR spectrum acquired along with a pseudo signal for absolute quantification. B. Averaged 31P metabolite concentrations for 5 mice. C. A setup for *in vivo* mouse leg muscle quantification for the measurement in A.

Results and Discussion

^{31}P muscle metabolites were quantified for mouse hind-limb muscles by using the dual tuned ^{1}H/^{31}P RF probe shown in Fig. 2. ^{31}P metabolite concentration values were well within the expected range for normal mice reported in the literature. The dual tuned probe allowed ^{1}H MRI/MRS as well as ^{31}P MRS for each leg without changing RF coils and animal positions. There are several advantages of using the dual tuned RF coil: use of the coil 1) reduces total acquisition time for serial ^{1}H/^{31}P MR acquisitions because back to back acquisitions are possible between ^{1}H imaging on both legs and ^{31}P localized spectroscopy for a single leg muscle without repositioning an animal 2) guarantees identical region of interest between ^{1}H MRI/MRS and ^{31}P MRS measurements and 3) provides high signal-to-noise ratio and spatial resolution by using two separate solenoid coils with filling factors maximized for mouse legs and high gradient coils.

Conclusions

We described an absolute quantification approach adapted for metabolite quantification of mouse skeletal muscles using synthetic signal injection method and an optimized dual tuned ^{1}H/^{31}P RF coil. This approach allows reliable ^{31}P metabolite determination in small animal muscles.

References

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Acknowledgements

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