A gQUCESOP method for accurate muscle CEST by considering the co-existence of PCr and Cr at 1.9 ppm

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INTRODUCTION:

Metabolic assessment of muscle function using CEST-MRI is promising and attracting many animal and human studies. To simplify signal interference in vivo, most studies estimate creatine-weighted signal located at +1.9ppm from water[1], while only calculate one PCr peak at 2.6ppm and neglect another one at 1.9ppm. However, during muscle contraction or exercise, the signals at 1.9ppm always include the contribution from both Cr and PCr. Herein, considering the co-existence of Cr and PCr signal at 1.9ppm within muscle, we included the CE-parameters from both Cr and PCr in a previously-developed gQUCESOP method[2]. This method may allow more accurate estimation of fractional concentration (f_b) values for both Cr and PCr, as well as the exchange rate k_b that reflects the microenvironmental pH.

METHODS:

In phantom experiment, a phantom containing 40mmol/L PCr, 10mmol/L Cr with pH=7.0 was prepared. Besides, phantoms containing Cr with different pH values were also employed to assess the pH-k_b relationship of Cr. In animal experiment, a slice containing skeletal muscles of the posterior neck of a rat was scanned. The temperature of phantom or rat during scanning was maintained at 36℃. A 9.4T MRI scanner was used in the experiments. Various saturation offset $\Delta\omega$ (from 2.3ppm to 3.0ppm for the PCr peak at 2.6ppm, and from 1.7ppm to 2.2ppm for Cr) and amplitude B_1 (from 0.4μT to 1.6 μT) were taken in CEST data acquisition. The saturation time of the continuous-waved saturation pulse was 1.5s, and SE-EPI with TR=2.0s was used for imaging. B_0, B_1, T_1 and T_2 maps were also acquired. A ^{31}P MRS was also taken to obtain a gold-standard pH value in the skeletal muscles.

The CE-parameters of the PCr peak at 2.6ppm was firstly obtained by using the gQUCESOP method. Then, according to the relationship of the CE-parameters of the two peaks of PCr at 2.6ppm and 1.9ppm respectively[3], the contribution of PCr on the $R_{1\rho}$ values around +1.9ppm was estimated. Finally, the CE-parameters of Cr were fitted using the corrected data. Besides, as a comparison, the CE-parameters of Cr were also calculated using the uncorrected data which neglected the PCr signal.

RESULTS:

A pH-k_b relationship of Cr at 36℃ is illustrated. k_b of Cr would be around 500s^{-1} with pH=7.0. A previous study[4] has shown that the f_b of 10mmol/L Cr in water solution would be about 0.0004. After considering the PCr signal, the f_b and k_b of Cr in the PCr-Cr phantom could be correctly calculated. On the contrary, when neglecting the PCr signal, the fitted k_b of Cr is significantly underestimated. In the *in vivo* study, the pH values obtained from k_b of Cr, k_b of PCr and ^{31}P MRS are highly similar. Besides, the concentration of Cr is in agreement with previous studies.

DISCUSSION and CONCLUSION:

By phantom experiment at 9.4T, we validated the modified gQUCESOP method for Cr-PCr co-quantification at 1.9ppm. The pH measurement was also proved by ^{31}P-MRS, with the exchange rates (k_b) from both Cr and PCr correlating with pH values. With advanced acquisition and noise-insensitive tools[5,6], this method has potential for human muscle CEST.

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Figure caption

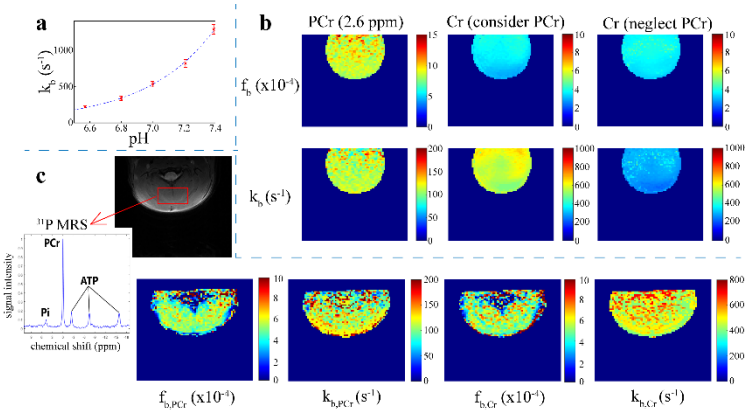

Figure 1 (a) The k_b-pH relationship of Cr at 36℃, namely $k_b = 17 + 5.12 \times 10^{\mathrm{pH}-5}$. **(b)** The result of the PCr-Cr phantom. It is shown that a correct Cr quantification could be obtained only if the PCr signal has been considered. If neglecting PCr signal, the k_b of Cr would be underestimated. **(c)** The structural image of the slice, and the fitted CE-parameters of PCr and Cr. For Cr, $f_b = (5.8 \pm 0.9) \times 10^{-4}$, corresponding to approximate 10 mmol/L considering the water concentration in muscle; besides, $k_b = 497 \pm 68\ s^{-1}$, corresponding to pH=6.97 $\pm$ 0.05. For PCr, according to its k_b, pH=7.05 $\pm$ 0.08. The ^{31}P MRS results in a pH of 7.05.