

Quality of Proton Magnetic Resonance Spectroscopic Imaging (MRSI) with and without an Endorectal Coil: a Phantom Study

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Introduction

Multiple studies have shown the potential of proton magnetic resonance spectroscopic imaging (MRSI) for the management of prostate cancer by evaluating choline + creatine/citrate (CC/C) ratio[1]. A major issue in proton MRSI of the prostate is the use of an endorectal coil[2], which is uncomfortable and sometimes intolerable for patients with prostate cancer. At a magnetic field strength of 3T, 3D MRSI with a clinically acceptable spatial resolution and measurement time has been presented with only a combination of external surface coils[3]. To evaluate the quality of spectral fitting of the CC/C ratio at different field strengths and coil use, we performed proton MRSI on a prostate phantom with external array coils and/or an endorectal coil at 1.5T and 3.0T.

Materials and methods

All MR examinations were performed with a 1.5T MR system (Avanto; Siemens, Germany) and a 3.0T MR system (Trio Tim; Siemens, Germany). The body RF coil was used for excitation of the MR signal, and a spinal array coil and an abdominal array coil, together with a disposable endorectal coil, were used for signal reception. The phantom is a small container with sunflower oil, with in the center a glass sphere (6 cm in diameter) with an aqueous solution of citrate (90 mM), creatine (12 mM), and choline (9 mM) at a pH of 7.4. In total, the phantom is 20 cm in height, 25 cm in length and depth, respectively. The endorectal coil was fixed in a shaft beneath the bottom of the glass sphere and the phantom was positioned on top of the spine array coil table and covered with the abdominal array coil (Figure 1). There are soft pads with thickness of 3 cm between the surface coils (the spinal array coil and the abdominal array coil) and the phantom.

For an overview of the phantom, a T2W sequence was used to acquire images in three directions. Then 3D proton MRSI was performed with magnetic field dependent echo times to acquire proton MR spectra from the aqueous solution in the sphere. The scan steps for the 1.5T scanner were similar as those for the 3.0T scanner: 1) Fixing the phantom and all the coils. 2) Manual shimming (optimization of the main magnetic field homogeneity) of the aqueous solution. 3) Performing MRSI with all the coils to acquire proton MR spectra from the aqueous solution. 4) Performing the same MRSI pulse sequence as Step 3 with only the endorectal coil. 5) Performing the same MRSI pulse sequence as Step 3 with only surface coils. 6) Manual shimming (optimization of the main magnetic field homogeneity) of the aqueous solution volumes again, starting from tune-up. 7) Repeating Step 3, 4 and 5.

The planes or 2D partitions from the 3D dataset from the top to the bottom of the glass sphere were defined as Plane 1, 2, 3.....and 7. For evaluation and quantification of the spectra, a software package (Metabolite Report; Siemens, Germany) was used to fit the time-domain signals from each voxels with model signals of citrate, choline and creatine. The CC/C ratio of each voxel was calculated automatically. If choline, creatine or citrate of any voxel was evaluated and quantified as zero, the CC/C ratio of this voxel would be excluded for statistic analysis because of bad fitting of spectroscopic data. Statistical analysis were all performed with SPSS 11.0. Multi-way analysis of variance (ANOVA) among groups was performed for the CC/C ratio of each voxel. The fixed factors for grouping were magnetic field, coil, shimming and plane. $P < 0.05$ was considered to indicate statistical significance.

Results

The CC/C ratio of different magnetic field, coil and plane is illustrated in Figure 2. Apart from the edges, the CC/C ratios looked quite homogeneous and the ANOVA result showed that the CC/C at 1.5T is different from 3T ($P < 0.001$), because of a different optimal echo time for the strongly coupled citrate spin system at different fields. Although for both field strengths, the CC/C ratios of all voxels in planes 3 to 5 were very similar ($P = 0.123$), there were some significant differences with different coil use, shimming or plane ($P < 0.001$). The different local shim (close to edge of sphere) had deviating CC/C ratios (Figure 3).

Conclusion

The software package can produce similar results throughout large parts of the phantom. Since the CC/C ratios acquired in different magnetic fields coils are different, the criterion for diagnosis (thresholding CC/C for cancer suspicion) should also be different, or this difference should be taken into account in calculating the CC/C ratio in a field-strength independent way. When line widths become larger, chances increase on calculating differing CC/C ratios. Care should be taken in comparing CC/C ratios of different tissues with strongly differing shim.

Reference

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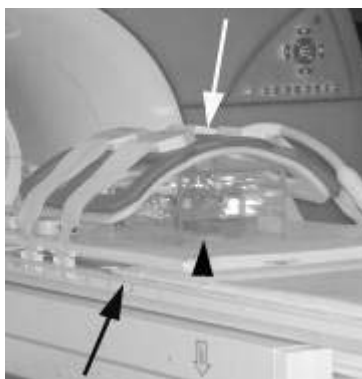


Figure 1: Location of the abdominal coil (white arrow), the spinal coil (black arrow) and the endorectal coil (arrow head).

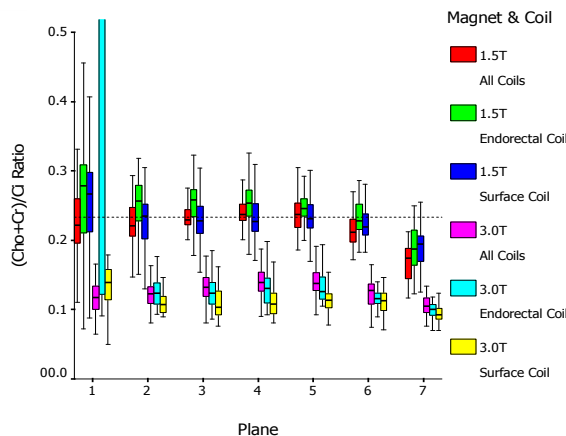


Figure 2: The CC/C ratio of different magnetic field, coil and plane. Apart from the edges (Plane 1, 6 and 7), the CC/C ratios looked quite homogeneous

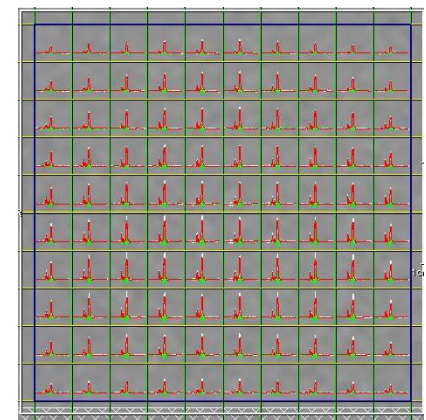


Figure 3: Spectral map of Plane 4 at 1.5T field. Apart from voxels close to edge of sphere, each spectrum looked quite similar. In all voxels spectra from 1.0 to 4.0 ppm are visualized with the white line. The red line is the fit to the spectrum, and the green line is the residual