In-vivo ^{31}P chemical shift imaging sensitivity improvement utilizing high dielectric pads

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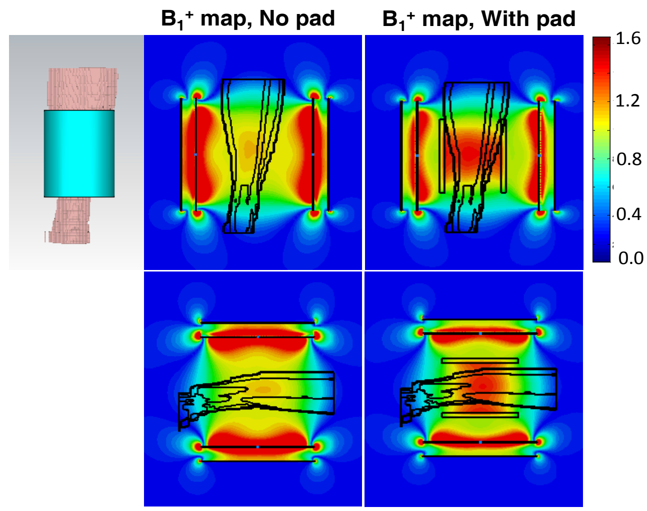
Target audience. Scientists interested in high field ^{31}P spectroscopy and imaging

Purpose. ^{31}P spectroscopy and imaging benefit greatly from ultrahigh field MRI. However, voxel sizes are typically still quite large and the low phosphorus metabolite concentrations require long acquisition times. In previous work it has been demonstrated that the image signal-to-noise ratio (SNR) can be improved by using high dielectric pads [1-4]. This work has mainly focused on in vivo ^{1}H imaging at 3T and 7T. Since the ^{31}P resonance frequency at 7T is very similar to that of ^{1}H at 3T, this approach should also feasible for ^{31}P imaging and spectroscopy at 7T. Initial phantom results were presented recently using a material with a relative permittivity of ~1000 at 7T, but no in-vivo data have yet been demonstrated [5]. Although this high permittivity can be beneficial for ^{31}P imaging, such high values can also strongly degrade the ^{1}H image. Here, we show the first in vivo results of ^{31}P CSI with improved SNR with a dielectric pad with an intermediate relative permittivity of ~300 ($BaTiO_3$).

Methods. Electromagnetic simulations of B_1^+ field were performed using FIT (finite integration technique) software (CST Microwave Studio). The setup included a birdcage coil loaded with the CST Bio model "Laura": simulations were performed with and without high permittivity dielectric pad. All B_1 maps were normalized to an accepted power of 1 watt. In vivo images (including two volunteers in this study) were acquired on a Philips 7T whole body system, with a custom-built tunable quadrature phosphorus birdcage, with proton excitation via microstrip elements [6]. Two dielectric pads of 18x18 cm^2 size and ~1-1.5cm thickness were positioned adjacent to the leg in the region of interest. After positioning of the dielectric, the coil was retuned to correct for the difference in loading. ^{31}P 2D CSI scan parameters were – FOV 20x20 cm^2, phase encoding matrix 10x10, flip angle 60°, echo time of 1.2 ms, repetition time of 2000 ms, number of averages 16. A scout proton image for overlay was acquired with low-tip angle gradient echo sequence. SNR measurements were made by integrating the phosphorus spectral signal.



Results. Figure 1 shows the results of the electromagnetic simulations , indicating an improvement in the B_1^+ field with the high dielectric pad by a factor of approximately 50%. Figure 2 shows the ^{31}P 2D CSI results both with and without the pad. Based on the integrated SNR, representing a ^{31}P image, the average SNR improvement was estimated as ~1.4, in reasonable agreement with the results from simulations.

Figure 1: B_1^+ field simulations with and without high dielectric pad imaging a leg at frequency of 121MHz

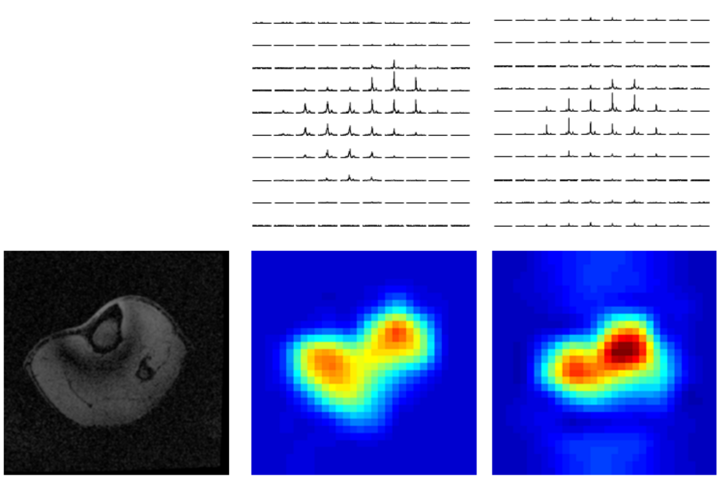


Figure 2: (left) Central slice of a 2D multi-slice image dataset. (top and bottom centre) 2D ^{31}P CSI data set and image from the integrated signal intensity, no dielectric pad. (top and bottom right) Corresponding 2D ^{31}P CSI and integrated image using the dielectric pads. Small changes in the geometry and compression of the leg can be seen in the with/without pad configurations.

Conclusions. The results show that the ^{31}P spectroscopy and imaging can be improved by using high dielectric pads, which can be designed to fit the particular leg geometry of the patient.

References. [1] Haines K. et al. J.Magn.Reson. 2010; 203: 323-327. [2] Yang Q.X. et al., Magn Reson Med. 2011; 65:358–362. [3] Teeuwisse W.M. et al., Magn Reson Med. 2012; 67:912-918. [4] Brink W.M. et al. Magn.Reson.Med. 2014; 71: 1632-1640. [5] Rupprecht S., et al., Proc. Intl. Soc. Mag. Reson. Med. 2014:22. [6] Zhang X. et al., Magn Reson Med. 2001; 46:443–450.