Lipid suppression for brain MRI and MRSI by means of a dedicated crusher coil

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Introduction: Proton MR spectroscopic imaging (MRSI) provides spatially resolved metabolic information mapped of the human brain. Spatial resolution in MRSI is limited by the relatively low SNR, due to the relatively low concentrations as well as the long TR of most MRSI sequences. Moreover, one needs to exclude signals from the skull that contain high intensity lipid signal in a poorly shimmed environment, causing corruption of the spectra in the brain due to point-spread and ghosting. To mitigate these effects, practically all MRSI sequences applied to the human brain use either volume preselection boxes (i.e. STEAM, PRESS, sLASER) and/or outer volume suppression (OVS). As a consequence, repetition times (TR) will be long hence the sampling duty-cycle in MRSI are typically very low (i.e. < 10%), leading to suboptimal SNR per unit of time. Here we have developed a crusher coil [Crowley JMR 1986] for MRI/MRSI of the brain that removes signals from the outer volume and puts no minimal constraints on the TR since no RF is used for lipid suppression. A switched current in the local conductors causes local B_0 field disturbances on the skull region (fig 1 b,c), which dephases the skull signal before signal detection.

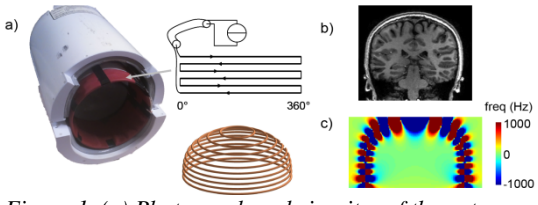

Figure 1. (a) Photograph and circuitry of the outer volume crusher coil, integrated inside a commercially available head coil. The thickness of the crusher coil is approximately 5 mm. The rods are bent to enclose the head, and generate a variable local field distortion (c).

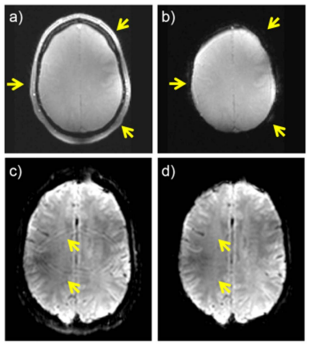

Figure 2. Lipid suppression with the crusher coil in a proton density image (a vs b) and single shot EPI (c vs d).

Methods: A crusher coil was built (MR Coils BV) and shifted inside a 16-channel (Nova Medical, USA) receiver array (Fig 1). The crusher coil was interfaced to one of the non-used B_0-shim amplifiers of the 7T system (Philips, Cleveland) and controlled via a commercially available dynamic shim update unit (Resonance Research Inc, USA) to switch on after the RF pulse and off again before the signal detection (fig 3b). Both imaging (proton density & EPI) and slice selective pulse-acquire MRSI (TR=1s, VAPOR water suppression, voxel=5x5x10mm^3, 14 min) was performed with and without application of the lipid crusher. With a 2-pulse CHESS water suppression, a ultra short TR (110ms) could be realized (voxel=3x3x10mm^3) leading to a scan time of only 5 min for 2D MRSI, although the water suppression was not optimal over the whole slice.

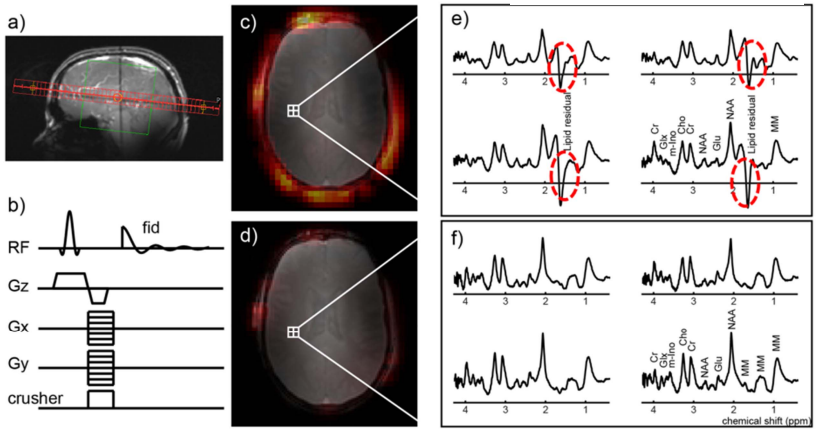

Figure 3. Pulse acquire MRSI (b) without (c,e) and with (d,f) lipid suppression with the crusher coil show a large reduction of lipid artifacts (red circles) in the spectra.

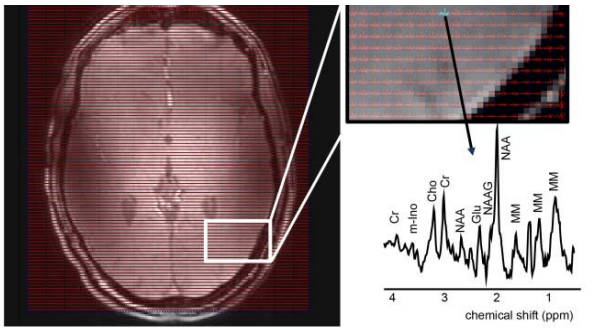

Figure 4; high resolution 2DMRSI (0.1cc) acquired in 5 min.

Results: Effective localized signal crushing can be obtained with the use of an inserted crusher coil, as indicated by the absence of signals from the skull (Fig 2a) and reduced EPI artifacts (Fig 2b). Since the crushing does not require any additional RF power deposition, fast and SNR optimized MRSI is feasible as indicated by the high spatial resolution and effective suppression of signals from the skull (Fig 3/4).

Discussion: Ultra high resolution MRSI is feasible by replacing SAR demanding localization and outer volume suppression techniques with a local crusher coil. As TR values can be reduced by orders of magnitude, SNR can be optimized. SNR at the spatial resolution of 0.1 cc was still more than sufficient to pick up many metabolites. So far, only a single slice was obtained, but this approach can be extended to a full 3D brain acquisition with echo planar readouts. Consequently, proof of concept is shown that fast metabolic imaging of the human brain would be feasible with a 7T MRI system equipped with a local crusher coil.