Automatic Prescription of 3D MRSI with Optimal Coverage and Outer Volume Suppression

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Introduction: Current MRSI protocols that utilize PRESS volume selection require that the region being excited is kept relatively small in order to avoid artifacts from the subcutaneous fat and sinuses. This limits the areas where tumors can be detected and means that, in many cases, only part of the tumor is covered. Manual prescription of an MRSI exam is also time-consuming and requires operator training. This has resulted in limited adoption of MRSI in clinical setting, despite significant advantages in the diagnostic ability that it presents. The goal of this project was to develop a technique that automatically prescribes a PRESS MRSI exam that maximizes the coverage of the brain, while simultaneously optimizing the prescription of the outer volume saturation bands. As such, the current strategy represents a significant advancement on the earlier work that was reported in (1).

Methods:

Image processing: A series of T1-weighted spoiled gradient echo (SPGR) images or T2-weighted FLAIR images was acquired on a 3T GE MR scanner using a commercially available 8 channel head coil. A brain tissue mask was generated using k-means clustering. A set of 3D points that defined the brain shape (Fig. 1, blue) was generated by casting rays onto the brain mask.

Acquisition parameter optimization: An optimal PRESS box placement was generated using Matlab by optimizing position and orientation of 6 planes. The planes were constrained to form a rectangular prism that could be rotated around the X axis. Optimal parameters were found using BFGS Quasi-Newton method by minimizing the following cost function:

$$f = \sum_i \min_j(d_{i,j}^2)) + w_d \cdot |D| + w_p \cdot \sum_{d_{i,j}>0} d_{i,j}$$

where: $d_{i,j}$ – distance from point i to plane j, D – measure of distances of all planes from origin, w_d, w_p – weights.

The positions and orientations of 9 sat bands were calculated by minimizing the same cost function with a constraint of symmetry along the X axis.

Acquisition: Calculated PRESS box and sat band parameters were saved as a file to be loaded into the MRSI pulse sequence. An 18x18x16 PRESS MRSI dataset was acquired (isotropic nominal voxel size = 10 mm, TE = 144 ms, TR = 1300 ms, T_{acq} = 8 min) with an EPSI flyback sequence. Raw data were processed offline using software developed in our laboratory.

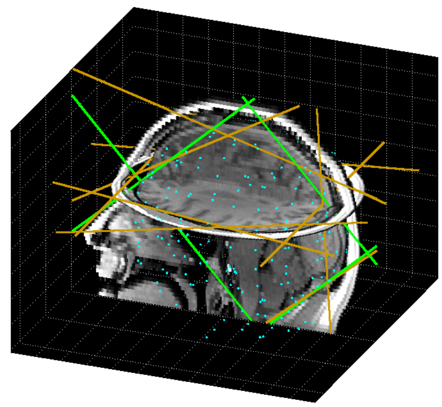

Fig.1: Calculated placement of PRESS box (green) and sat bands (orange)

Results: The previously described technique (1) that involves automatic sat band and manual PRESS box placement has been implemented as an option in our clinical research protocol and has been used on 27 patients to date. Average coverage of the brain by selected volume was 773 cc, compared to 240 cc for the standard protocol. No detectable increase in lipid artifacts within the brain has been observed. The new algorithm has been tested on images from a number of previously acquired datasets of healthy volunteers and patients with brain tumors. Fig. 1 shows an example of calculated PRESS box and sat band prescription. The total calculation time (2.8 GHz Intel Xeon processor) was around 30 seconds. The average coverage of the brain was estimated to be 1100 cc, a 4.6x increase over the standard protocol. Fig. 2 shows an MRSI dataset from a healthy volunteer, acquired with calculated sat bands and a representative oblique PRESS volume prescription that was chosen based on results of the calculation.

Discussion: This technique allows the collection of PRESS MRSI data from almost all of the brain in a single acquisition. Automatic placement of the oblique PRESS box extends the coverage into inferior areas of the brain, while avoiding artifacts from the orbits and sinuses. Optimal placement of sat bands ensures effective lipid suppression and allows the PRESS box to extend beyond the brain boundary. The improved coverage will be used in evaluating heterogeneous and infiltrative tumors as well as tumors at the periphery of the brain. Automatic prescription will also reduce the variability between exams and ensure that the data are acquired from the same volume of interest (Fig. 3), allowing improved characterization of disease progression in serial studies of response to therapy. It will also reduce the need for extensive operator training, which is currently a significant barrier in the wider spread adoption of MRSI.

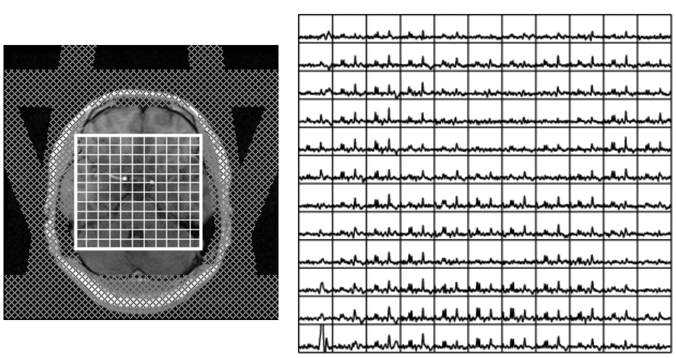

Fig.2 (left): One slice from oblique 3D MRSI dataset

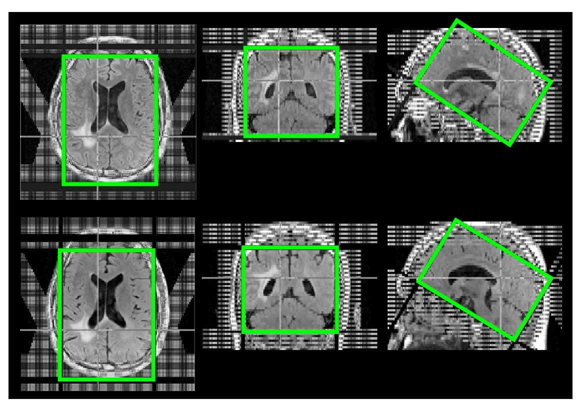

Fig.3 (right): Calculated prescription for two different exams of the same patient

References and Acknowledgements: [1] Ozhinsky E, et al. Proc. 16th ISMRM, 2008. [2] Li T, et al. Proc. 14th ISMRM, 2006: 3086 [3] Osorio J, et al. Proc. 15th ISMRM, 2007. [4] Tran TK, et al. Magn. Reson. Med. 2000;43: 23-33. I wish to thank Adam Elkhaled for help in collecting data and Esin Ozturk for help with data analysis. This research was funded by UC Discovery grant ITL-BIO04-10148 in conjunction with GE Healthcare