Improved Spatial Coverage for 3D MRSI by Automatic Placement of Outer-Volume Suppression Saturation Bands

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Introduction: Excitation of subcutaneous lipids has been a major problem in 3D brain MR spectroscopic imaging (MRSI) and has limited the coverage obtained. Current protocols place the selected volume - Point Resolved Spectroscopy (PRESS) box within the bounds of the brain and reduce lipid contribution by placing saturation bands over the edges of the head. Because of the curvature of the head, manual placement of saturation bands is a time consuming and difficult task that introduces variability. To improve coverage of the brain, while simultaneously reducing lipid contamination, we have developed a technique for automatic optimization of sat band position and orientation that simultaneously maximizes coverage of subcutaneous fat and minimizes the portion of brain tissue that is removed. This allows to prescribe a much larger PRESS box and provides MR spectra from a significantly larger volume of the brain. The method includes acquisition of a conventional MR image volume with high lipid/tissue contrast, calculation of sat band parameters to cover the lipids in that image volume and integration of those parameters into the spectroscopy pulse sequence.

Methods:

Image acquisition: A series of 92 T1-weighted spoiled gradient echo axial images was obtained (flip angle = 20, slice thickness = 3 mm, T_{acq} = 1min) on a 3T GE MR scanner. The acquisition parameters were chosen to achieve maximum contrast between subcutaneous lipids and brain tissues. Only the lowest 64 slices were used in the analysis to make sure that the entire top of the head was covered without wrap-around artifact. Images were automatically downloaded from the scanner to a separate computer, running Linux operating system for processing.

Segmentation: Lipid and brain tissue masks were generated using thresholding. To account for variability in image intensity, the thresholding limit was calculated based on analysis of image histogram. Morphological closing and opening was performed on lipid and brain tissue masks respectively to remove artifacts of thresholding.

Sat. band parameter calculation: The algorithm optimized position, orientation and thickness of 9 saturation bands and was implemented in Matlab. It seeks a configuration where the sat bands cover most of the lipids, but as little brain tissue and air as possible by minimizing a cost function, similar to that in [1]: $f = -w_f \cdot N_f + w_b \cdot N_b + w_a \cdot N_a + w_d \cdot d$, where w_f, w_b, w_a, w_d – weights, N_f, N_b, N_a, - number of fat, brain, air pixels, covered by the bands, d – measure of distances of all bands from origin. The Nelder-Mead simplex method was chosen to find minimum of this function since it did not impose a requirement that the cost function be differentiable.

Due to the large number of degrees of freedom, simultaneous optimization of all parameters was impractical. Instead, optimization was done in several stages on subsets of parameters. During the first stage only the locations of sat bands were optimized, then locations and tilt angles of the bands in the sagittal plane, then in the axial plane and so on. For each stage, the weights were tuned to ensure the fastest convergence.

To further reduce the number of parameters to optimize, the assumption was made that the problem is symmetrical in the right-left direction. To improve the performance of the calculation of the cost-function, segmented masks were sub-sampled by a factor of 3 in X and Y directions.

Pulse sequence A file with saturation band parameters and a series of images with overlays showing the placement of sat bands was generated and uploaded to the scanner. The 3D MRSI pulse sequence was modified to allow reading of the parameters of up to 16 additional bands from a file. These bands were used in addition to fixed bands at the edges of the PRESS selected volume.

Acquisition: Using the calculated sat band prescription an 8-channel 18x18x16 spectroscopy dataset was acquired (isotropic nominal voxel size 10 mm, TE = 144 ms, TR = 1500 ms) with an EPSI flyback sequence. Raw data were processed offline using software developed in our laboratory.

Results: During technique development, data from phantom, healthy volunteers and brain tumor patients has been acquired. Calculation time for the sat band locations using a 2.8 GHz Intel Xeon computer was around 3 minutes. Fig. 1 shows an example of the calculated sat band placement. Fig. 2 shows one of the slices from the MRSI acquisition. For the volunteers and patients it was possible to acquire useful data from approximately 600 1cc voxels compared to 256 voxels using a conventional acquisition. The total acquisition time was 8 minutes. Lipid peaks were present in some of the edge voxels, but caused no significant interference with spectra inside the volume defined by sat bands.

Discussion: Using the technique described above it was possible to acquire MRSI data from a 2.5-fold larger volume of the brain. This will increase the value of MRSI in evaluating tumors near the edge of the brain that are currently difficult to cover due to the curvature of the brain. Effective outer volume suppression with these oblique sat bands makes unnecessary the requirement that the whole PRESS box lies completely within the bounds of the brain. Automatic placement of sat bands may also help reduce variability in the quality of the scan that is inherent in manual prescription. Unlike methods described previously [2], the position of the sat bands was optimized in three dimensions and a 3D MRSI dataset was acquired.

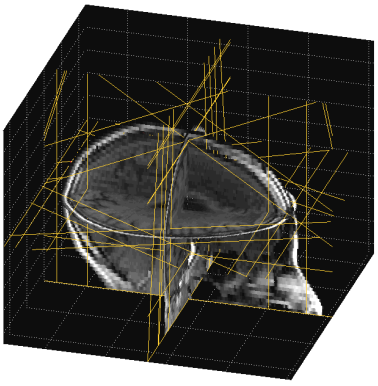

Fig.1: calculated placement of sat bands

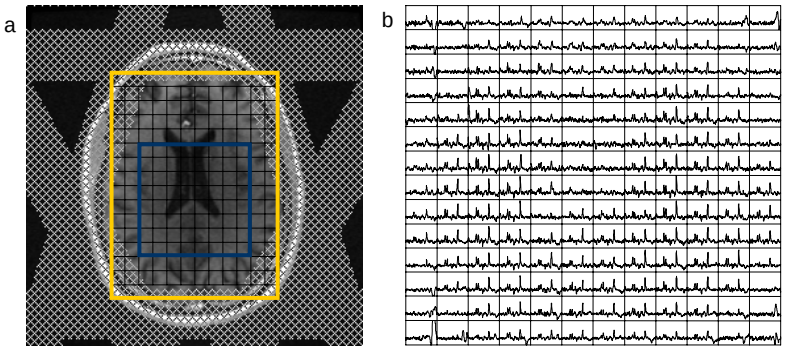

Fig.2: a) PRESS box prescription and sat band position. 16x12x6 cm selected volume shown in yellow. Conventional 8x8x4 cm MRSI selection shown in blue for comparison. b) one slice from acquired MRSI dataset

References and Acknowledgements: [1] Li T, et. al. Proc. 14th ISMRM, 2006: 3086 [2] Osorio J, et. al. Proc. 15th ISMRM, 2007. [3] Tran TK, et al. Magn. Reson. Med. 2000;43: 23-33. [4] Le Roux P, et al. J Magn Reson Imaging, 1998; 8(5): 1022-32. This research was funded by UC Discovery grant ITL-BIO04-10148 in conjunction with GE Healthcare