Lipid Unaliasing for MR Spectroscopic Imaging of Gliomas at 3T Utilizing Sensitivity Encoding (SENSE)

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Introduction: It is estimated that 18,400 malignant tumors of the brain or spinal cord will be diagnosed during 2004 in the United States, and ten times as many world wide [1]. 3D MRSI has been successfully employed to extract information about brain tumor cellularity and cell membrane breakdown, cellular energetics, and neuronal activity through its ability to differentiate signals coming from choline (Cho), creatine (Cr) and N-acetyl aspartate (NAA) molecules [2]. Singlet lipid and doublet lactate peaks can be observed in the abnormal brain tissue. Lactate is a byproduct of anaerobic glycolysis, and is expected to be present in areas with poor oxygenation. Lipid is bound to cell membrane in normal brain cells, and if detected in MRSI might indicate the cellular membrane breakdown due to cell death. Subcutaneous lipid resonances might be excited with Point RESolved Spectroscopy (PRESS) volume selection due to the low bandwidth of the selection pulses that creates what is known as the chemical shift artifact [3], which aliases into the small spectral FOV. Lipid aliasing is a bigger problem at higher field strength, due to the increased chemical shift artifact. It is important to identify the origins of lipid resonances for accurate assessment of the disease state. In this study, we propose a post-processing method for unaliasing lipid resonances originating from in-slice subcutaneous areas from the 3D MRSI of gliomas at 3T using the sensitivity information of an eight channel phased-array coil and sensitivity encoding method (SENSE) [4]. Although the SENSE method was originally proposed for unaliasing reduced FOV images arising from faster data scan approaches, it is possible to generalize SENSE method to solve any type of aliasing problems, such as ghosting due to phase shift and flow errors in EPI cardiac imaging [4]. The lipid unaliasing technique is proposed to increase the accuracy of lactate assessment, and Cho, Cr, and NAA quantification.

Materials And Methods: The study was performed on a 3 T clinical MR scanner (GE Medical Systems, Milwaukee, WI) equipped with an eight channel RF coil. The imaging sequence included the acquisition of axial 3D SPGR, and proton-density weighted coil sensitivity images. ^{1}H 3D MRSI was acquired using PRESS volume localization with CHESS water suppression and VSS pulses for outer volume suppression. The spectral array dimensions were 12x12x8 with 1 cc nominal spatial resolution. The rectinlinear *k*-space sampling was restriucted to a central eleliptical region to provide a scan time was 9 minutes with TR=1.1s, and TE=144 ms. Spectra from individual coil elements were processed on a Sun UNIX Workstation using software developed in our laboratory [6]. A software program to remove the in-plane aliasing lipid resonances from the spectral array was implemented using Matlab 6.5 (The Mathworks Inc., Natick, MA). Proton density weighted coil sensitivity images for each coil element were divided by the square root of the sum of squares image of the coil sensitivities, and smoothed to reduce the anatomy related inhomogeneities of the maps by applying median and low-pass homomorphic filters. Coil sensitivities were resampled to twice the spectral resolution in both x and y directions. After the pre-processing, spectral array was treated as if it was a half FOV representation of an extended spectral array, and spectra outside the main array within twice the spectral FOV was calculated using the resampled coil sensitivities and the SENSE methodology. The resulting array included the subcutaneous lipid areas. The methodology was tested on the spectra of an MRS phantom that contained Cho, Cr, NAA, and lactate with a lipid filled balloon attached to the outer surface to produce lipid aliasing. Unaliasing routine was also applied to reduce lipid contamination in a Grade 4 glioma patient. 24 lipid contaminated voxels from the phantom spectra, and 12 voxels from the patient spectra were selected, and lipid area and height reduction was assessed. For each spectrum, water baseline was removed by fittting the water peak, and lipid was normalized with the water height. Mann Whitney rank sum test was used to assess if the magnitude of the lipid height and areas were significantly changed by utilizing the unaliasing routine.

Results: Figure 1 shows the phantom setup along with the spectral selections. The MRS phantom with the lipid balloon attached to the side is shown on the top left. The original spectral FOV is marked with the white grid, and the red grid represents the selected spectral volume. Spectra on the blue grid are shown before and after the unaliasing procedure that was applied on the top and bottom right, respectively. Shown in the yellow box is the lipid spectra calculated by the unaliasing algorithm. It was found that unaliasing program significantly reduced aliasing lipid areas (p=0.0351) by a median of 42.54± 24.86%, and lipid heights (p=0.0043) by a median of 51± 17.58%. Maximum and minimum reduction of lipid areas were 84.12% and 7.25%, and lipid heights were 82.74% and 34.68%, respectively. Figure 2 shows the spectral results for the glioma patient case. The original spectral FOV is shown on the top left, and the extended FOV is shown on the top right with the white grids. The red grid represents the spectral excitation volume, and the blue grid marks the lipid contaminated areas. Spectra from the blue grid are shown before and after the unaliasing procedure on the bottom left and right respectively. Yellow box marks the lipid areas unfolded using the algorithm, and its spectra is shown on the bottom right. For the patient case, unaliasing algorithm significantly reduced the lipid areas (p=0.0029) by a median of 54.84± 16.32%, and lipid heights (p=0.0020) by a median of 59.54± 12.36%. Maximum and minimum reduction of lipid heights were 76.93% and 22.1%, and lipid areas were 84.77% and 29.46%, respectively.

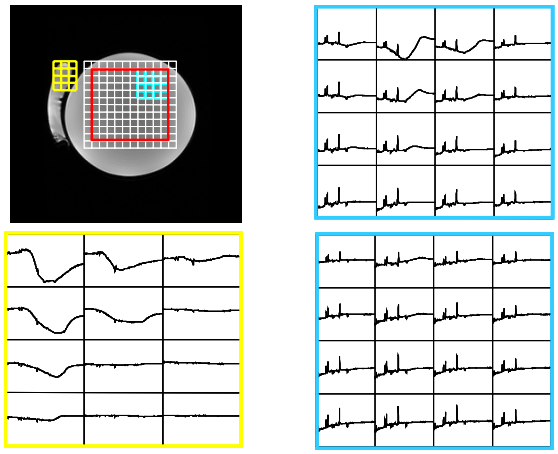

Figure1. MRS Phantom

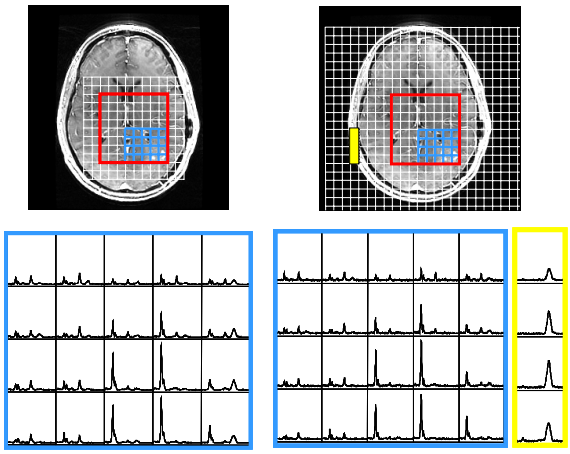

Figure 2. Grade 4 Glioma Patient

Discussion: Lipid contamination was observed to be more severe in the right to left (RL) compared to the anterior to posterior direction (AP), because the current PRESS spectral volume excitation pulse in that direction has a smaller bandwidth, resulting in more chemical shift artifact. Lipid resonances on the right side of the volume were stronger due to the directionality of the chemical shift artifact, resulting in more contamination on the left side of the spectral array. Lipid resonances might also alias into the spectral FOV from superior or inferior (SI) locations rather than in-plane, which can not be resolved by this algorithm due to the lack of coil sensitivities in that direction. Echo planar spectroscopic imaging (EPSI) is expected to allocate time for double spectral coverage in the SI direction, which will eliminate lipid contamination from other slices, and enhance the lipid reduction combined with this unaliasing procedure.

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