# Magnetic Resonance Spectroscopy of Breast Cancer using the SLIM Technique – Initial Results

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**Target Audience:** Imaging scientists and clinicians interested in spectroscopic imaging methods and/or MRS of breast cancer.

**Background:** Magnetic resonance spectroscopy (MRS) can provide clinically valuable metabolic information about breast cancer. Consistently acquiring high-quality MRS data in the breast, however, can be very challenging. Single-voxel spectroscopy can produce high-quality spectra, but it requires expertise to appropriately position the MRS voxel and make appropriate adjustments while the patient lies in the scanner. Chemical shift imaging (CSI) allows for retrospective selection of a region of interest because it provides spatial information, but CSI generally produces lower spectral quality than SVS in breast due to less-optimal $B_0$ shim and the "bleeding" of lipid signals between voxels that causes baseline distortions. Our goal is to use *Spatial Localization by IMaging* (SLIM) technique *(1)* as an alternative reconstruction method for conventional 2D phase-encoded CSI acquisitions. Rather than map metabolite spatial distribution, we seek to use SLIM to produce a single spectrum from a target lesion, thus providing a robust alternative to single-voxel MRS that does not require careful shimming or voxel placement, and is therefore more practical for use in clinical practice.

**Purpose:** To present initial MRS results from breast cancer patients using SLIM, compare the results to conventional Fourier transform reconstructions, and explore the impact of SLIM reconstruction variations.

**Theory:** The SLIM technique treats the measured k-space data as a linear combination of signals from a discrete set of spatial compartments with homogeneous signal (after correction for $B_0$ variation *(2,3)* and coil sensitivity profiles *(4)*). The measured signal is described as:

$$p_{n,l}(t) = \sum_{m=1}^{M} c_m(t) \int \chi_m(\vec{r})\, S_l(\vec{r})\, e^{-i\vec{k}_n\cdot\vec{r}}\, e^{-i2\pi\Delta f(\vec{r})t}\, d^3\vec{r}$$

, where $p_{n,l}(t)$ is the measured time-domain signal from the $l^{th}$ receive coil and the $n^{th}$ phase-encode with k-vector $k_n$, $c_m(t)$ is the pure time-domain signal from compartment $m$, $\chi_m(\vec{r}) \in [0;1]$ is the fractional density of compartment $m$ as a function of space $r$, $S_l(\vec{r})$ is the complex spatial sensitivity profile from element $l$, and $\Delta f(\vec{r})$ is the spatial frequency offset. The equation is converted to matrix form and inverted to produce a least-squares solution for the compartmental signal $c_m(t)$. With sufficient oversampling (#phase encodes x #coils >> # compartments) the reconstructed spectra $FT\{c_m(t)\}$ represent the compartmental average even for inhomogeneous compartments.

**Methods:** Five female patients with biopsy-proven breast cancer were scanned on a Siemens 3T TRIO with a 16-ch Sentinelle breast coil. Using a 3D fat-suppressed gradient echo for planning, a unilateral, oblique coronal plane was selected for water-fat (*aka* Dixon *(6)*) imaging (3D gradient echo, TR=9 ms, TE=2, 3, 4, 5, 6, 7 ms, resolution ~1 x 1 x 3 mm, 3 minutes) and for CSI acquisition (TR/TE=1500/30 ms, 12 mm slice, 16x16 matrix, 192 mm FOV, 6.4 minutes). The 6-point water-fat image data was reconstructed into a $T_1$-corrected fat fraction map and $B_0$ map using a combination of methods from the ISMRM Fat-Water Toolbox (*7-9*). A manual ROI was drawn on the tumor using the anatomical images; additional SLIM compartments were defined by thresholding and segmenting the fat-fraction images (as shown below). To compare with conventional reconstruction, the same data were Fourier transformed (FT), and voxels overlapping the ROI were summed after frequency and phase correction.

**Results:** Of the five patients scanned, only one patient had a visible tCho resonance with either SLIM or FT reconstruction methods. Figure 1 shows the planning images for this case and the reconstructed SLIM spectra using a simple 2-compartment model. Comparing the FT reconstruction to SLIM (Fig 1e,f), SLIM produces similar spectral quality, but with narrower linewidth and increased noise. Both spectra show a detectable tCho peak. Figure 2 shows the effect of different compartmentalization strategies on SLIM localization. The best result was achieved by segmenting the breast tissue outside the ROI into water and fat compartments, thus improving their compartment homogeneity.

**Discussion:** This is the first demonstration of SLIM-reconstructed spectra in breast cancer, which shows the feasibility of measuring tCho *in vivo* with performance similar to conventional CSI. The potential advantage of SLIM is that it can incorporate prior knowledge into the reconstruction to improve spectral quality. In this case, the SLIM approach gave narrower linewidths because the B0 distribution was known and modeled in the reconstruction. Ongoing work will include accruing additional patients, exploring additional compartmentalization strategies, and using optimized k-space sampling (known as SLOOP *(10)*) to improve localization performance.

**Conclusion:** SLIM can reconstruct breast spectra with quality comparable or better than conventional Fourier transform reconstruction.

**References:** 1) Hu X, et al., MRM 1998; 2) Bashir A, et al., MRM 2006; 3) Khalidov I, et al., IEEE Trans Med Imag 2007; 4) An L, et al., MRM 2011; 5) Liang and Lauterbur, JMR B 1993; 6) Dixon WT, Radiology 1984; 7) Hu HH, et al., MRM 2012; 8) Berglund J, et al., MRM 2010; 9) Hernando D, et al, MRM 2010; 10) von Kienlin M, JMR 1991

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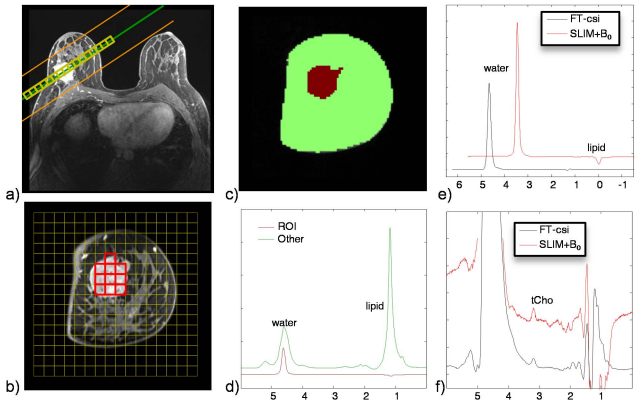


Figure 1 – Planning image (a) and CSI grid (b) used for a 2-compartment (c) SLIM reconstruction. Resultant spectra (d) show good localization. Comparing the SLIM ROI spectrum with the FT reconstruction in (e) and (f), SLIM slows narrower linewidth but increased noise compared to FT-CSI.

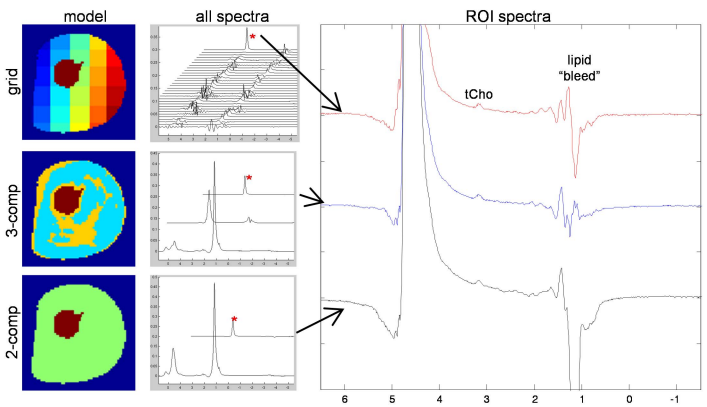


Figure 2 – Comparison of compartmentalization strategies. The non-ROI region was divided using a spatial grid (top) and by water content (middle). All three models produce an ROI spectrum with measureable tCho but variable lipid "bleed".