An Interactive Software for 3D Chemical Shift Imaging Data Analysis and Real Time Spectral Localization and Quantification

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Introduction: Magnetic resonance spectroscopy is a relatively new diagnostic method for non-invasive characterization and quantification of molecular markers with clinical utility for providing detection, identification and treatment for a variety of diseases. Chemical Shift Imaging (CSI) is a preferred method to obtain high-resolution localized NMR spectra *in vivo* from both proton and phosphorous metabolites. However, the clinical utilization of this method has been impeded by the challenge of analyzing and displaying the large amount, often thousands, of spectra acquired in accordance with the three dimensional structures across a volume of tissues. Here we present a novel software package, *3D Interactive CSI* (3D*i*CSI), a user-friendly, intuitive and multi-functional program that provides the crucial link between the CSI data-acquisition and its clinical interpretation.

Material and Methods: 3D*i*CSI has been developed using C++ on a Windows platform and has a flexible structure that allows importation of data acquired on different scanners. Designed from the start to cope with the challenges of 3D CSI, 3D*i*CSI is capable of importing a variety of multidimensional data sets: 1D, 2D single/multi slice and 3D CSI data. Parameters that are pertinent to data analysis, such as Field of View (FOV), pixel and voxel size, image orientation and position, etc, are either read from data file headers directly or manually entered. 3D*i*CSI displays the MR image overlaid with the corresponding CSI slice and metabolic map, each of which can be easily turned on or off. The spectra of selected voxels of interest are displayed separately for individual analysis.

3D*i*CSI has an elaborate toolbox for multidimensional spectral processing: the data set can be phased, zero-filled, spatially smoothed, filtered, and baseline-corrected and the changes are displayed in real-time; temporal filtering (Lorentzian, Gaussian, or combined) as well as phasing and baseline correction routines are interactively parameterized to best match the signal. For proton spectra, water signal is removed using time convolution [1] and lipid suppression is accomplished through data extrapolation [2]. For phosphorus spectra, convolution difference, linear fitting and quadratic fitting are available to perform baseline correction. CSI data set can be interpolated to higher spatial resolution and multiple data sets can be summed or subtracted.

For spectral localization and quantification, the CSI grid can be interactively shifted in all three spatial dimensions simultaneously with spectra updated in real time; Multiple spectra can be selected and averaged; A user-defined region can be drawn on the image and the spectrum within this region is estimated and displayed in a separate window; Quantification of a single metabolite or the ratio of two is achieved using either area integration or Principal Component Analysis (PCA) [3].

3D*i*CSI provides project reports in HTML format that contain the image, spectra, metabolic map, and corresponding parameters. Individual spectrum can also be exported in different formats to be compatible with other programs. To facilitate the volume processing of similar exams, the sequence of desired spectral processing steps can be recorded in a macro file and applied to all the exams in a batch mode.

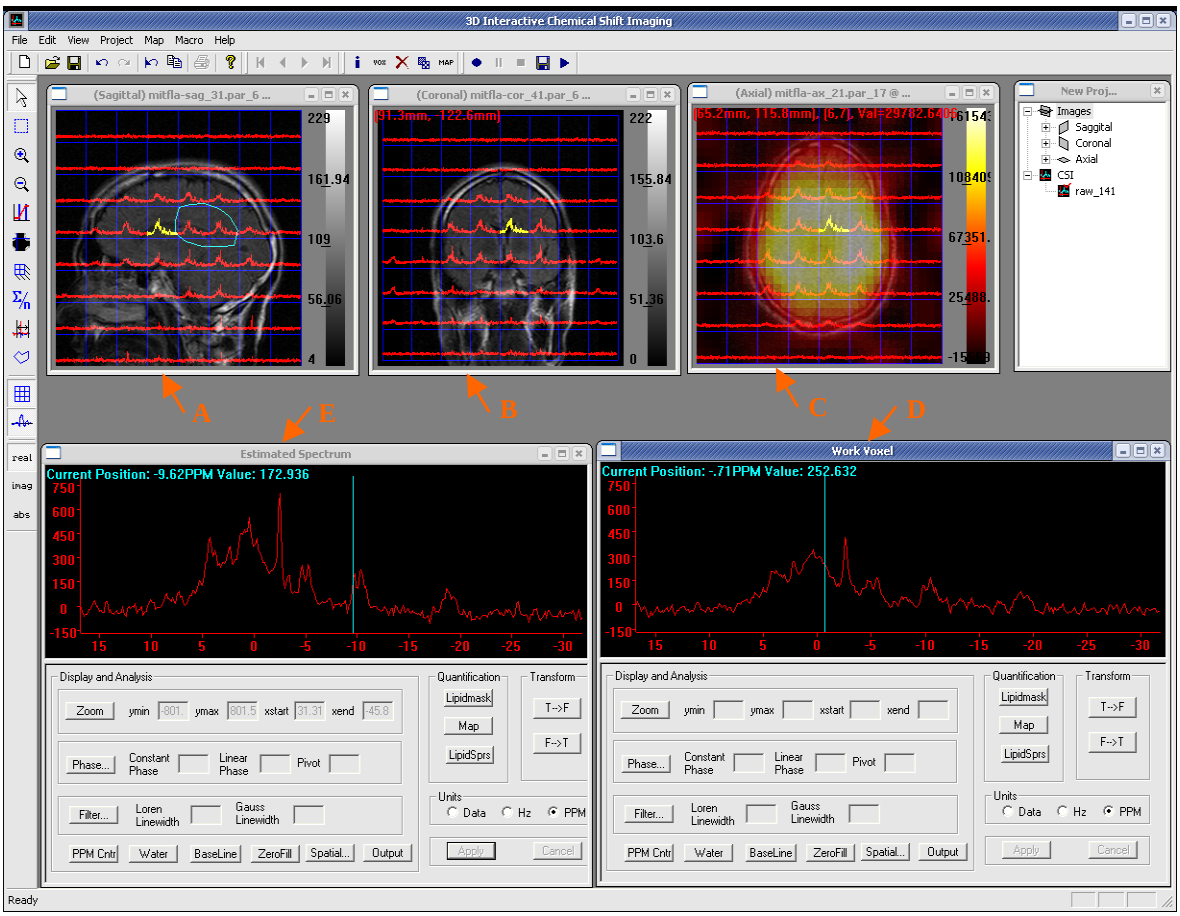

Figure 1. Screenshot from the 3D interactive CSI software

Results: Figure 1 is a screenshot from 3D*i*CSI. A ^{31}P 8×8×8 3D CSI data set was acquired on a 1.5T Philips scanner, with TR of 1600ms, 512 data points, and 240mm FOV. Window A, B, and C display images in three orientations overlaid with CSI slice, with window C also showing Phospho-Creatine map. The real spectrum of the selected voxel (highlighted as yellow) is displayed in window D. The CSI data set is phased and filtered using a 5Hz Lorentzian filter. Window E shows the estimated spectrum from a user drawn region (the blue polygon shown in window A).

Reference: [1] Sodano, P. and Delepierre, M., *J. of Magn. Reson.* A 104, 88-92, 1993; [2] Haupt, C.I., et al, *Magn. Reson. In Med.* 35, 678-687,1996; [3] Stoyanova, R. and Brown, T.R., *J. of Magn. Reson.* 154, 163-175, 2002