Automatic repositioning of CSI grids in ^{1}H MRS: impact on reproducibility of metabolite concentration measurements

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Introduction

Longitudinal ^{1}H chemical shift imaging (CSI) studies that follow disease progression or response to treatment are becoming more and more common [1]. In such studies, reproducible measurements of metabolite concentrations are of paramount importance, to ensure maximum sensitivity in detecting the effect of the disease or treatment, in an individual or on a group basis. One of the factors that can significantly impact the reproducibility of metabolite concentration measurements is the accuracy of repositioning the CSI grids. While *a posteriori* image registration and CSI data re-sampling have recently been shown to significantly decrease scan-to-scan variability [2], such approach might not always be adequate. In particular, correction using this approach cannot be performed out of plane for single slice CSI data sets (if the follow-up slice has been slightly shifted out of plane with respect to the baseline slice), or for the edge voxels of the CSI grid if a rotation is observed between the baseline and follow-up (f/u) CSI grids (due to, eg, head rotation). We present here the results of a study designed to minimize scan-to-scan variability by using *a priori* image registration, followed by the acquisition follow-up CSI data sets with identical coverage and orientation as the baseline scans.

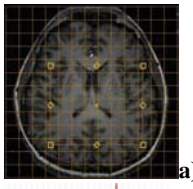
Methods

All the scanning protocols described below were done on a 3T, whole body GE scanner. Four normal volunteers were scanned three times during the course of one day. The subjects were removed from the scanner between the three daily sessions. The baseline scan was comprised of a half brain axial localizer (1.16 x1.16 x 2mm resolution), followed by the acquisition of a single slice, 16x16 CSI PRESS data set (voxel size=1.38 x 1.38 x 1cm, TE/TR=144/1500, 6.4min total acquisition time). In each of the repeat scans, an axial half brain localizer was obtained, which was registered to the initial localizer [3]. A triple oblique volume was then acquired, having the same orientation and coverage as the baseline localizer scan. Subsequently, two CSI data sets were acquired in the f/u scans (with their order being randomized): one was placed on the axial localizer, using visual inspection of the baseline CSI grid location for repositioning precision, and the second one was repositioned on a triple oblique slice, using the positioning information offered by the registration algorithm.

MRS data was analyzed using LCModel; fits were performed between 1 and 3.85ppm. Voxels whose content was CSF dominated (defined as having NAA concentration less than 1/3 of the maximum NAA) were removed from the data analysis. Overall CSI grid overlap and individual voxel overlaps were also calculated for both the visually and automatically repositioned voxels using a procedure described elsewhere [3].

Results and discussion

Figure 1a presents the typical location for the positioning of the CSI grid, and Figure 1b a typical spectrum from a homogeneous brain region.. The spectra included in the analysis had line widths between 4Hz (from homogeneous white matter) and 10 Hz (from inhomogeneous regions surrounding the caudate nucleus and the putamen).


a)


b)

Figure 1:
a) *Location for the CSI grid* ***b)*** *typical spectrum and fit*

Table 1 presents the average % standard deviations (% SD's) over all the volunteers and all the voxels for the metabolites included in the data analysis. Here, %SD has been calculated as $\%SD = SD / mean * 100$, where both the standard deviation and the mean are calculated for each voxel out of 3 measurements for both visual and automatic repositioning. Besides removing the need for high-resolution localizer images and minimizing the possibility for human error, significant improvement in measurement reproducibility can be observed when the automatic repositioning procedure is used. It is to be noted, however, that even in the case when the automatic repositioning procedure was used, reproducibility only approached single digits; this is because we have decided to keep in the analysis the great majority of voxels, regardless of their position across brain regions with high iron contents (such as the putamen) or close to the skull. It is those voxels in particular that significantly increase overall variability.

	Cr	Cho	Cho/Cr	NAA	NAA/Cr
% SD visual repos.	19.0	19.3	19.6	13.7	16.8
% SD automatic repos.	13.5	14.7	11.8	13.4	12.5

Table 1: Average % SD for all the voxels and volunteers included in the study.

Mean overlap between the baseline and follow-up CSI grids were also calculated (Table 2). While whole grid overlaps were generally high for both repositioning procedures, indicating the fact that the same brain region was studied in all the follow-up exams, *individual* interior voxel overlaps are significantly smaller. This can be explained, eg, by the fact that a 2 mm offset of the CSI grid in the x dimension, eg, represents only 2% offset for the whole grid (whose x dimension is 8.25cm), while a 2mm shift for an individual voxel (whose x dimension is 13.75mm) represents 15% shift. Also, we have only presented the average overlap of the center voxel; for corner voxels, considering possible head rotation, this overlap can go to zero. This indicates that in plane *a-posteriori* CSI data re-sampling (at a minimum) has to be performed in longitudinal CSI exams. For out of plane errors in localizing f/u single slice CSI data sets, or edge voxels in the case of slightly rotated f/u CSI grid, however, CSI data re-sampling alone cannot correct for wrong CSI grid repositioning, and data has to be acquired from an identical anatomical location, using an approach similar to the one presented here.

	CSI grid	Center voxel
Visual repos. overlap [%]	83	67
Automatic repos. overlap [%]	95	89

Table 2: % overlap between baseline and f/u CSI grids and individual, interior center voxels.

Conclusions

We have presented a study designed to understand the impact of CSI grid repositioning methodology in longitudinal MRS exams. Reproducibility of metabolite concentration measurements and MRS volume overlap were compared for visual and automatic repositioning of CSI grids. Significantly increased volume overlap and better measurement reproducibility, along with improved exam workflow, were observed for the automatic repositioning procedure, suggesting this approach as the future of longitudinal MRS exams.

References

1. Krishnan et al, Am. J. Psychiat, **160**, 2003 (2003); **2.** W-J Chen et al, Proc ISMRM, 105 (2004); **3.** Hancu et al, NMR Biomed, **18**, 352 (2005).