Reduction of acquisition time in magnetic resonance spectroscopic imaging using 3D wavelet encoding method: Comparison to chemical shift imaging.

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Introduction: The wavelet encoding (WE) method has been tested in acquiring magnetic resonance Spectroscopic Imaging (SI) data [1]. Previously, results have shown that the 2D version of wavelet encoding reduces acquisition time and pixel bleed compared to Chemical Shift Imaging (CSI) [2]. Shaped RF pulses play the role of prototype functions, called wavelets, used in wavelet transform to localize sub-voxels according to a wavelet encoding scheme, which shortens data acquisition time and reduces cross-voxel contamination [3, 4]. To further demonstrate the usefulness of the wavelet encoding method we show here that the 3D version of the wavelet encoding using a modified 3D PRESS sequence provides accurate results on human subjects compared to CSI, while keeping acquisition time short.

Method: Wavelet encoding SI reduces acquisition time when encoding spatial information by performing multiple encoding steps while only waiting a small fraction of the full TR time in between acquisitions. The space to be imaged is divided into sub-voxels by increasing the selection gradient strength (Haar wavelet dilation) and shifting the RF pulses (Haar wavelet translation) [2, 3], as shown below. The sub-voxels along the diagonal axis are excited where only the effective time (T_{eff}) is required for each sub-voxel; thus acquisition time is reduced. There is a specific pattern that must be followed in order to prevent interference. A modified PRESS sequence is used for the 3D WE-SI technique (Figure 1). The process is basically the same as for the 2D sequence [2]. Single and dual band RF pulses, 7.2 ms duration 2 kHz bandwidth, and profiles resembling Haar wavelets, are used.

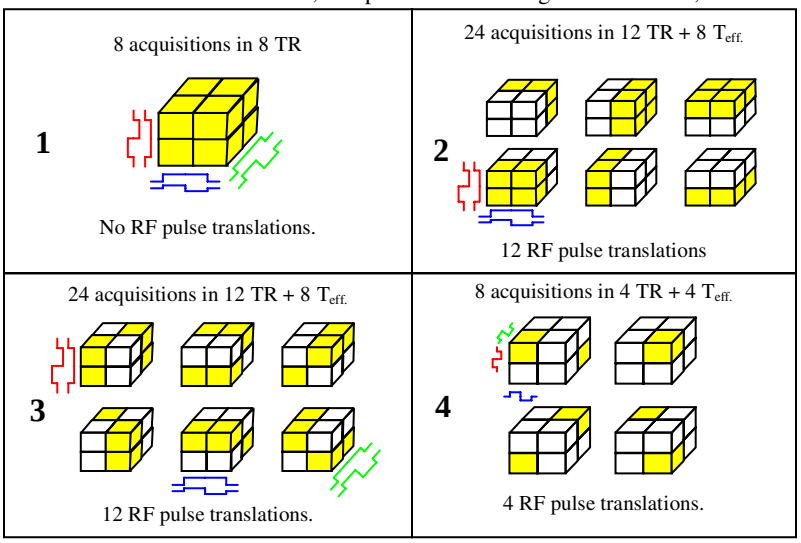
Figure 1: RF pulse combinations to reduce acquisition time in the 4 by 4 by 4 WE-SI. (T_{eff} = sequence timelength)

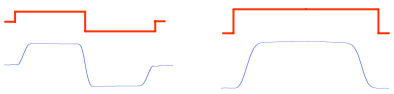
1) The imaged 3D space is fully covered in the 3 directions. Single and dual band RF pulses are applied along 3 axes.

2) The imaged 3D space is fully covered in 2 directions. Single and dual band RF pulses are applied along the corresponding axes.

3) The imaged 3D space is fully covered in 1 direction. Single and dual band RF pulses are applied along the corresponding axis.

4) Only dual band RF pulses are applied along 3 axes as the 3D space is not fully covered in any direction.





Wavelet function (red) and dual-band RF pulse profile (blue).

Scale function (red) and single band RF pulse profiles (blue).

Figure 2: Haar functions (red) and RF pulse profiles (blue)

Results/Conclusion: Figure 3 and Figure 4 below show a single slice of the results of a 4x4x4 data acquisition using both the CSI and WE-SI methods. Acquisition parameters are: TR= 2 s, TE =135 ms, FOV=8 cm, slice thickness=4 cm, 2 and 4 averages, and 1024 points, acquired on a 1.5 T GE scanner. Note that the specifics of the CSI PRESS sequence on the SAGE program result in only a 3x3 grid being displayed. Combining the results of 4 human volunteers obtained using LCModel [5], we found similar results on relative concentrations of NAA/Choline and NAA/Creatine when comparing the WE-SI to the CSI data (Table 1). As expected, the SNR is slightly lower for WE-SI compared to CSI [2]. However, the time required to obtain the data is significantly reduced for WE-SI as compared to CSI. The time reduction is directly proportional to the spatial resolution [2] ranging between 27.3 and 43.9% (Table 1). The 3D WE-SI method could be an alternative to the CSI method at low spatial resolutions where spatial distribution is preserved, and at high resolutions where acquisition time is reduced.

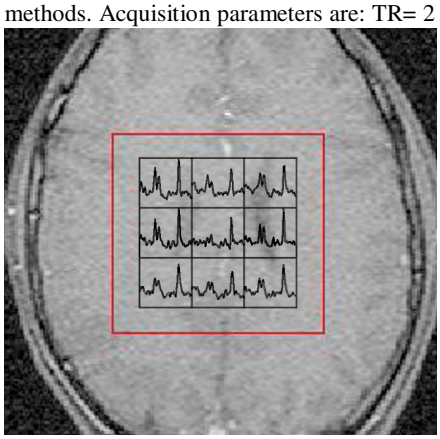


Figure 3: 3x3 CSI on axial brain MR image

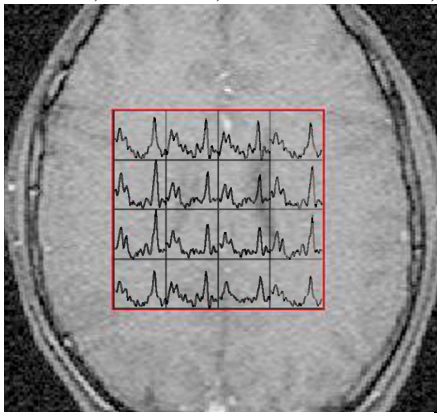


Figure 4: 4x4 WE-SI on axial brain MR image

	NAA/Cr	Cho/Cr	SNR (a.u)	Acqu. time	Acqu. time reduction (%)
CSI - 4x4x4	1.93 ± 0.77	0.31 ± 0.06	15.37 ± 7.32	256 sec (Nex=2)	-
WE - 4x4x4	1.76 ± 0.53	0.34 ± 0.11	11.10 ± 3.14	186sec (Nex=2)	27.3
CSI - 8x8x2	1.95 ± 0.51	0.35 ± 0.09	11.77 ± 4.02	1024sec (Nex=4)	-
WE - 8x8x2	1.94 ± 0.61	0.35 ± 0.11	6.60 ± 2.31	588sec (Nex=4)	42.6
CSI - 8x8x4	2.17 ± 0.93	0.39 ± 0.19	6.47 ± 2.35	1024sec (Nex=2)	-
WE - 8x8x4	1.88 ± 0.82	0.38 ± 0.15	5.21 ± 2.09	574sec (Nex=2)	43.9

Table 1: Comparison results of the CSI and the WE-SI methods on the average of 4 human volunteers.

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