Definition of the Neurochemical Patterns of Human Head Injury in ^{1}H MRS Using Wavelet Analysis

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BACKGROUND

Closed head injury results in a diverse pattern of anatomical and biochemical changes in the brain, reflected in ^{1}H magnetic resonance spectroscopy (MRS) [1]. The categorization of these changes is often complicated by the presence of underlying macromolecules and lipids, especially in severe cases of non-accidental injury in infants [2].

Continuous wavelet transform methods have been developed which allow time-series information to be described in both frequency and time simultaneously. This allows metabolites to be separated by both chemical shift and T_2^* characteristics [3].

AIMS

(1) Develop a descriptive and intuitive wavelet transform visualization mechanism for ^{1}H MRS free-induction decay (FID) analysis.
(2) Test the methods developed by classifying examples of ^{1}H MRS signal acquired from trauma patients.

METHODS

Patients: 3 trauma patients of varying severity (minor, moderate, and severe) and three controls were examined with ^{1}H MRS and Fourier transform (FT) [4] (GE 1.5T, STEAM, TE=30ms, TR=1.5s).

Morlet Wavelet Transform (MWT): MRS FIDs were first frequency shifted up 1 PPM in order to avoid the tremendously large scales (window sizes) needed to examine low frequencies. Then, by standard wavelet formulation [3,5], the FID was convolved with Morlet wavelet basis functions using scales linearly correlated with frequencies [5] in the range 4.3 to 0 PPM before shifting. A large Morlet wavenumber (ω_0=64) was employed in order to localize frequency content effectively. The resulting grid, containing FIDs filtered by frequencies, was then converted to colors representing isocontours in a manner that would resemble FT spectra.

RESULTS

The MWT panels strongly resemble the FT panels, reproducing decreased NAA in the moderate (Fig.1) and severe head injury (Fig.2) cases, as well as the only slightly reduced NAA of the mild head injury case (not shown). Major metabolites are present and identifiable in both the MWT and the FT.

In addition, MWT may help clarify or reinforce diagnosis of trauma. In the FT of the severe trauma case (Fig.2d), NAA is broader and taller than Cr. Measurements of severity based on NAA/Cr fail due to uncertainty regarding true [Cr], and quantitative measures fail due to the enlarged peak area at NAA. In the MWT of the severe case (Fig.2e), however, NAA appears reduced compared to Cr, suggesting that the peak observed at NAA is instead either lipids or underlying macromolecules. By contrast, in the moderate trauma patient, NAA visibility in the MWT (Fig.1d) shares the characteristics of the matched contralateral (Fig.1a), reinforcing the diagnosis of reduced, but real, NAA.

Notably absent from the MWT of the severe head trauma case, however, are lipids which dominate the FT of Fig.2d. The signal of lipids, due to its extremely short T_2 time, rapidly diminishes in time, in contrast to the signals of of NAA, Cr, Cho and mI, which have much longer T_2 times. The extremely strong initial amplitude of lipid is indeed visible in color (glowing a bright green), but when converted to black and white is less obvious. It is possible to FT the filtered FIDs displayed in the MWT panel, however, in order to examine the frequency response of the MWT. In the process we can see, from the two large resonances circled in Fig.2f, that lipids are indeed present in a high concentration, even if they are "hidden" in time.

DISCUSSION

The MWT method presented offers an intuitive bridge between frequency and time information which can clarify interpretation of complex head trauma spectra obtained with FT. The MWT, however, is not intended as a replacement for the FT, but rather a supplement that allows qualitative access to time related changes and takes advantage of the multiple dimensions available in a FID. Certainly the information obtained by the MWT and the FT are not mutually exclusive, nor mutually redundant.

CONCLUSIONS

(1) MWT is an effective tool in the examination of ^{1}H MR spectra.
(2) MWT lends added insight into the neurochemical impact of trauma.

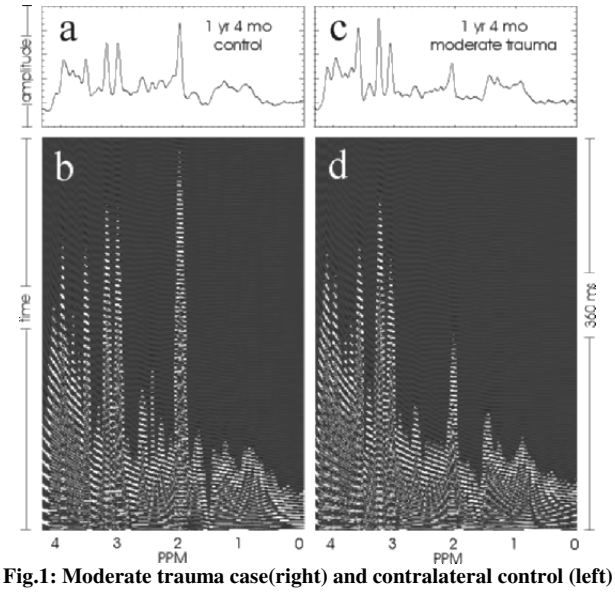

Fig.1: Moderate trauma case(right) and contralateral control (left)

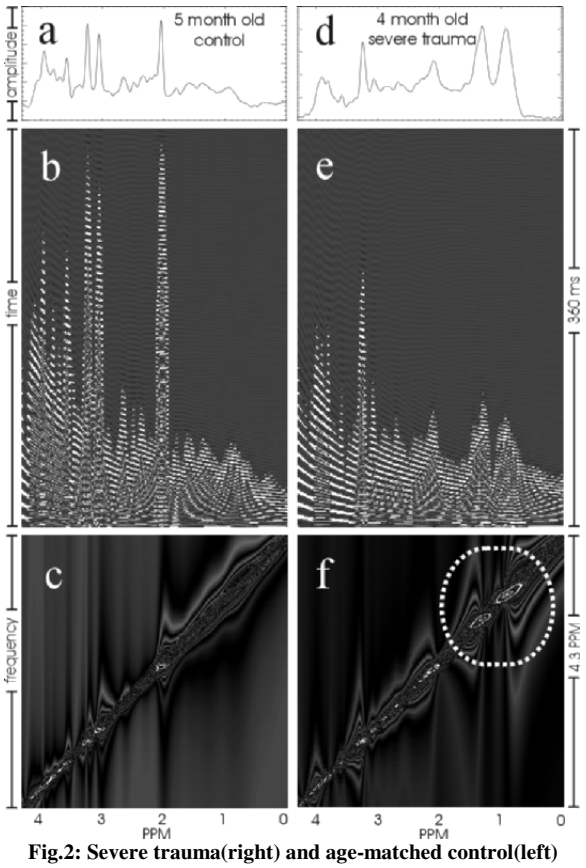

Fig.2: Severe trauma(right) and age-matched control(left)

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