

Motion Detection In Healthy Young, Middle-Aged, and Elderly Adults using a Water Signal Based Navigator Echo: A ¹H MRS Study

S. A. Wijtenburg¹, K. L. Fuchs², V. I. Simnad³, and J. Knight-Scott¹

¹Radiology, Children's Healthcare of Atlanta, Atlanta, GA, United States, ²Neurology, University of Virginia, Charlottesville, VA, United States, ³Neurology, Evergreen Hospital Medical Center, Kirkland, WA, United States

Introduction: Contrary to imaging, there is no standard technique for processing motion data from a ¹H magnetic resonance spectroscopy experiment. Here, we build upon our earlier work incorporating a CHESSE pulse into a STEAM sequence (1) by presenting a new method for analyzing and interpreting motion data collected from three age groups: healthy young (HY), healthy middle (HM), and healthy elderly (HE).

Theory: The MR signal can be represented by $S(t) = \int M_{xy}(r, 0) e^{-iy \int \Delta B(r, \tau) d\tau}$ where patient motion alters both the phase ($e^{-iy \int \Delta B(r, \tau) d\tau}$) and signal component ($M_{xy}(r, 0)$). Because the detected signal from the non-localized CHESSE pulse is from the entire head, it is sensitive to changes in the spatial distribution of spins and changes in intravoxel incoherence, resulting in detectable alterations in the water signal intensity. The careful shimming to maximize SNR and spectral resolution with ¹H MRS increases the sensitivity of the signal to small movements in the field.

Methods: Data Collection: A CHESSE pulse centered on the water frequency was added to a standard STEAM sequence (Figure 1). Data were collected from three healthy groups: HY (5 men, 5 women, mean: 25.7 ± 2.9 yrs), HM (6 men, 8 women, mean: 48.9 ± 2.7 yrs), and HE (4 men, 6 women, mean: 63.3 ± 1.9 yrs). The spectroscopic examination included STEAM (6 cm³, TR/TM/TE = 5000/10/10 ms, NEX=112, 2500 Hz SW, and 2048 complex pts) and a water reference experiment for phase correction. All data were collected in the posterior cingulate gyrus using a 1.5 T Siemens Magnetom Sonata MRI system.

Processing: Since the data is acquired from the entire head, motion is measured by changes in the global signal, which is measured N times where N=NEX. To calculate the change in signal from each acquisition, each peak is fit with AMARES (2) and the amplitude is recorded. To reduce the influence of outliers in data normalization using the maximum data point, the data is first sorted in ascending order, linearly regressed, and the final point in the regression used as the maximum signal. The data is normalized to the final point, and then another linear regression is applied to the normalized data to determine the slope. Due to the normalization applied to the data, the slope now corresponds to the average change in signal between acquisitions. For participants who remained motionless, the slope should be close to zero and if plotted, the data would look like a flat line. If the participant moves, this generates a positive slope for the regressed line.

Results: The mean slope with its CV (%) for HY, HM, and HE were $2.18 \times 10^{-4} \pm 55\%$, $4.48 \times 10^{-4} \pm 48\%$, and $5.43 \times 10^{-4} \pm 80\%$, respectively (Figure 2). Visually, it appears that HY moved the least in the group, but the CV of 55% was driven by one participant who moved twice as much the rest of the group. A one-way ANOVA on ranks of the slopes showed that only HY and HM were significantly different (p=0.016), the median of HM was larger than the median of HY. Overall, as age increased, mean participant movement increased with the most diverse being HE where some in the group were able to remain still comparable to HY while others moved significantly throughout the scan (Figure 3).

Discussion: Previously, we reported CVs to provide an indication of motion; however, they lack the ability to provide quantifiable indications of motion. Our new method quantifies motion through repeated linear regressions, thereby assessing motion through the severity of the slope and reducing the influence of outliers. For HY and HM populations, one can be fairly confident that the participant will remain relatively motionless for the duration of the study based on the mean slopes for each group. Unfortunately, the large HE slopes show that the reliability of this population to remain motionless for the duration of this study is low. Therefore, it is imperative that the elderly population be made as comfortable as possible to reduce patient repositioning, and perhaps the length of spectroscopic protocols should be adjusted to accommodate the increased likelihood of motion.

References: (1) Shanbhag DD et al. Proc Intl Soc Magn Reson Med 13 2005; 2505. (2) Vanhamme L et al. J of Magn Reson 1997; 129:35-43.

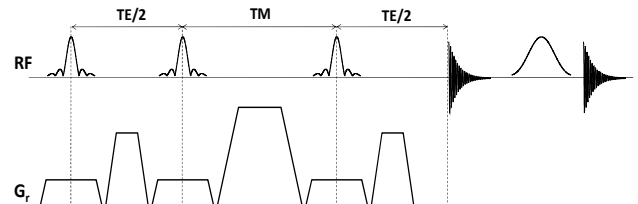


Figure 1. STEAM sequence with the additional CHESSE pulse: 17.5 Hz bandwidth Gaussian pulse, 51.2 ms in duration, centered on the water frequency, and acquired with a 26.6 ms TE.

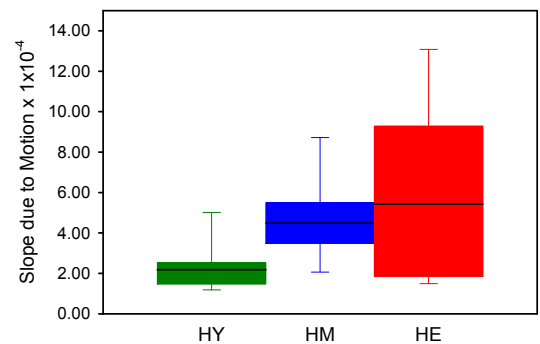


Figure 2. Boxplot showing how the slope or average change in signal between acquisitions differs for HY (■), HM (■), and HE (■).

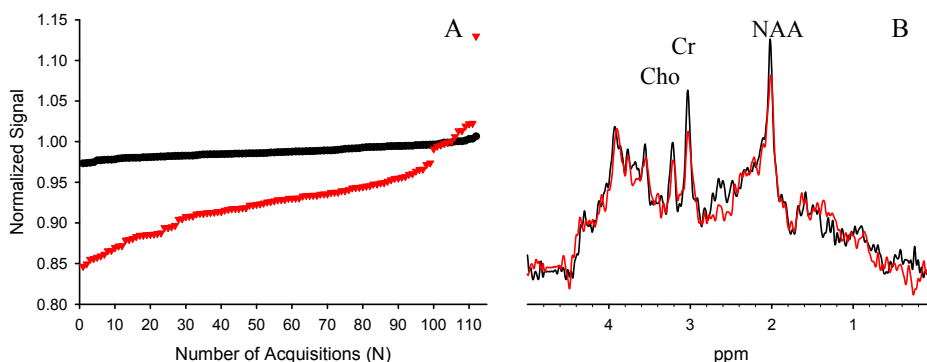


Figure 3. Changes in signal as a function of acquisition (A) are shown for two healthy elderly participants (● and ▲). Participant 1 moved very little evidenced by the nearly straight line (slope= 2.17×10^{-4}) whereas participant 2 moved greatly with slope= 12.7×10^{-4} . If the participant remained motionless, then the total signal for the normalized 112 acquisitions would be 112. Here, the percent signal difference between the actual total signal and motionless total signal was -1.9% for participant 1 and -7.9% for participant 2. Therefore, the more severe movement resulted in signal loss which contributed to the spectral intensity differences shown in (B).