Improved GABA editing and macromolecule suppression with adiabatic and highly selective Gaussian pulses at 7T
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Synopsis
The aim of the study is to improve the efficiency of GABA editing and macromolecule suppression at 7T. An asymmetric adiabatic pulse with transition bandwidths of 2800 Hz at 1.5 ms (A) and a symmetric Gaussian pulse with 88 of bandwidth (1.5 ms) was applied at 1.7 ppm to suppress macromolecules. In the GABA and lysine phantom tests, this scheme shows 9% signal loss improvement in comparison with highly selective GABA pulse without macromolecule suppression (8% of signal loss) and symmetric pulse (9% of signal loss).

Introduction
Gamma-aminobutyric acid (GABA) is the main inhibitory neurotransmitter and its detection by 1H MRS is hampered by its low abundance and spectral overlap with other metabolites such as creatine and macromolecules (MM). GABA is most commonly edited by classical MEGA editing. At 3T, due to limited spectral dispersion, MM is usually coedited with GABA leading to a GABA-to-MM measurement at 3 ppm. Although MM suppression schemes were proposed by applying asymmetrically shaped pulses symmetrically around ± 1.7 ppm (4) and ± 1.5 ppm, this method is very sensitive to frequency drift during the acquisition. Another way to suppress co-edited MM at 3 ppm is to use in vivo recovery, which will make the design of 1T relaxation and suffer from inhomogeneous GABA signal dispersion (1). Spectral dispersion increased further than 3 ppm with highly asymmetric editing pulses. It may allow improving efficiency of editing with minimal bandwidth contamination. MEGA was combined with sLASER technique to mitigate chemical shift displacement at 7 T, however, it is shorter time-jump delay in sLASER limits the use of long editing pulses with high selectivity. MEGA-SPECIAL sequence has been proposed at 3T but is limited to the incorporation long editing pulses. Therefore, to improve the chemical shift displacement and GABA editing efficient without coediting at 7 T, we implemented and compared three MEGA editing schemes in combination with semi-adiabatic sSPECIAL localization.

Materials and Methods
Three different frequency selection inversion pulse were generated for the study. A 40-μs nonadiabatic pulse has 136 Hz of transition bandwidth (< 0.95), < 0.95) for the one side and 500 Hz of bandwidth (M < 0.95), which consists of the first half of HS1 pulse and the second half of HS4 pulse. A 20-ms narrow Gaussian pulse has 960 Hz of bandwidth (M < 0.95) and 7 Hz of inversion bandwidth (M < 0.95) and 7 Hz of inversion bandwidth (M < 0.95). Drift correction, and phase correction were performed using Matlab 2018a (The Mathworks, Natick, MA, USA). For in vitro test, shimming was performed using the first- and second-order z-axis and x-axis shims with FAST(EST)MAP. The outer volume suppression and water suppression were interleaved prior to the sSPECIAL sequence. The following parameters were used TR/TE = 1000/80 ms; V1 = 20–25 Hz; bandwidth = 4000 Hz; average = 45; number of data points = 2048. For the in vivo measurement, one volunteer was scanned using the scheme with asymmetric adiabatic and narrow Gaussian pulses. The receiver-channel recombination, B0 drift correction, and phase correction were performed using Mattes 2015b (The Mathworks, Natick, MA, USA). For in vivo test, GABA and lysine peaks are integrated between 2.85 ppm and 3.15 ppm.

Results
Figure 2 illustrates the normalized GABA and lysine signal intensity at 3 ppm by three MEGA-SPECIAL scheme: A) asymmetric pulse and narrow Gaussian pulses, B) symmetric pulse and narrow Gaussian pulses, and C) narrow Gaussian pulse. In the asymmetric scheme, the normalized signal intensity is higher than in symmetric and narrow Gaussian pulses. This increase is due to the reduced chemical shift sensitivity, which is consistent with the theoretical analysis. The difference between the two asymmetric adiabatic pulses is small, which indicates that the GABA signal intensity is not strongly dependent on the asymmetric parameter. The normalized signal intensity for the symmetric scheme is lower than for the asymmetric schemes, which suggests that the symmetric scheme is less efficient in GABA editing.

Discussion
We compared the performance of the first time MEGA-SPECIAL method with a combination of asymmetric adiabatic pulse and narrow Gaussian pulses, which improved the efficiency of GABA editing and MM suppression at 7T.

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References

Figures
Figure 1. The semi-adiabatic MEGA-SPECIAL sequence scheme. The subspectra subtraction scheme is presented on the right side.

Figure 2. (A–C) Normalized integral of GABA (in blue) and lysine (in black) signals acquired by asymmetric adiabatic pulse and narrow Gaussian pulse, symmetric pulse and narrow Gaussian pulse, and narrow Gaussian pulse. In the asymmetric scheme, the normalized signal integral is higher than in symmetric and narrow Gaussian pulses. This increase is due to the reduced chemical shift sensitivity, which is consistent with the theoretical analysis. The difference between the two asymmetric adiabatic pulses is small, which indicates that the GABA signal integral is not strongly dependent on the asymmetric parameter. The normalized signal integral for the symmetric scheme is lower than for the asymmetric schemes, which suggests that the symmetric scheme is less efficient in GABA editing.

Figure 3. (A-D) 1H MRS of the in vitro test. A) 2900 Hz; average = 128, number of data points = 2048.

Figure 4. The semi-adiabatic MEGA-SPECIAL sequence scheme. The subspectra subtraction scheme is presented on the right side.