Early Brain Tumor Detection by Fixed-Point Spin Dynamics and Active-Feedback MR Imaging

Chaohsiung Hsu[1], Zhao Li[1], and Yung-Ya Lin[1]

[1]Chemistry and Biochemistry, UCLA, Los Angeles, CA, United States

Target audience Physicians and physicists interested in the early detection of brain tumor, glioblastoma multiforme (GBM), preclinical animal studies, and orthotopic mouse models.

Purpose Early detection of high-grade malignancy, such as glioblastoma multiforme (GBM), using enhanced MRI techniques significantly increases not only the treatment options available, but also the patients' survival rate. For this purpose, a conceptually new approach, termed "Active-Feedback MR", was developed. An active feedback electronic device was homebuilt to implement active-feedback pulse sequences to generate avalanching spin amplification and fixed-point spin dynamics, which enhances the local magnetic-field gradient variations due to irregular water contents and deoxyhemoglobin concentration in early GBM.

Methods The general principles of the "Active-Feedback Controlled MR" can be found in our publications [1-4] (and references therein). Here, its specific applications to early GBM detection were developed and demonstrated. (i) First, an active-feedback electronic device was home-built to generate feedback fields from the received FID current. The device is to filter, phase shift, and amplify the signal from the receiver coils and then retransmit the modified signal into the RF transmission coil, with adjustable and programmable feedback phases and gains. The MR console computer can execute the active-feedback pulse sequences to control the trigger signal, feedback phase/gain, and the duration of the feedback fields, allowing us to utilize the active feedback fields in novel ways. (ii) Next, an active-feedback pulse sequence was developed for early GBM detection and was statistically tested on *in vivo* orthotopic GBM mice models, as shown in Fig. 1. It is a phase-cycled repeating block of [cw-pi-cw], where active-feedback field is also on during the cw (continuous wave) pulse to enhance the contrast originated from local magnetic-field gradient variations due to irregular water contents and deoxyhemoglobin concentration in early GBM. In essence, the enhanced GBM contrast arises from "selective self-excitation" and "fixed-point dynamics" generated by the bulk water 1H under active feedback fields. [5-6]
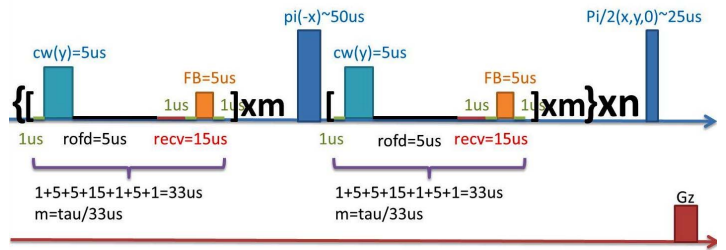

Fig. 1: An active-feedback pulse sequence was developed for early GBM detection and was statistically tested on *in vivo* orthotopic GBM mice models.

Results Stage-1 orthotopic GBM mouse models infected with human U87MG cell line were imaged. Representative results from 5 mice were shown in Fig. 2. While T2 parameter images (3rd column), T2-weighted images (4th column), and T1-Gd-weighted images (5th column) could not successfully locate the early GBM tumor, our active-feedback fixed-point images (2nd column) and decay constant mapping (1st column) successfully highlight the early GBM tumor with a close correlation with histopathology (6th column). Statistical results (N>10) show that this new approach provides 5-6 times of improvements in GBM tumor contrast, as measured by "contrast-to-noise ratio" (CNR) or "Visibility".

Conclusion *In vivo* orthotopic xenografts GBM mouse models validated the superior contrast/sensitivity and robustness of this approach towards early GBM detection. Statistical results (N>10) for GBM mouse models at various cancer stages, alternative active feedback pulse sequences with further improved performance will also be presented.
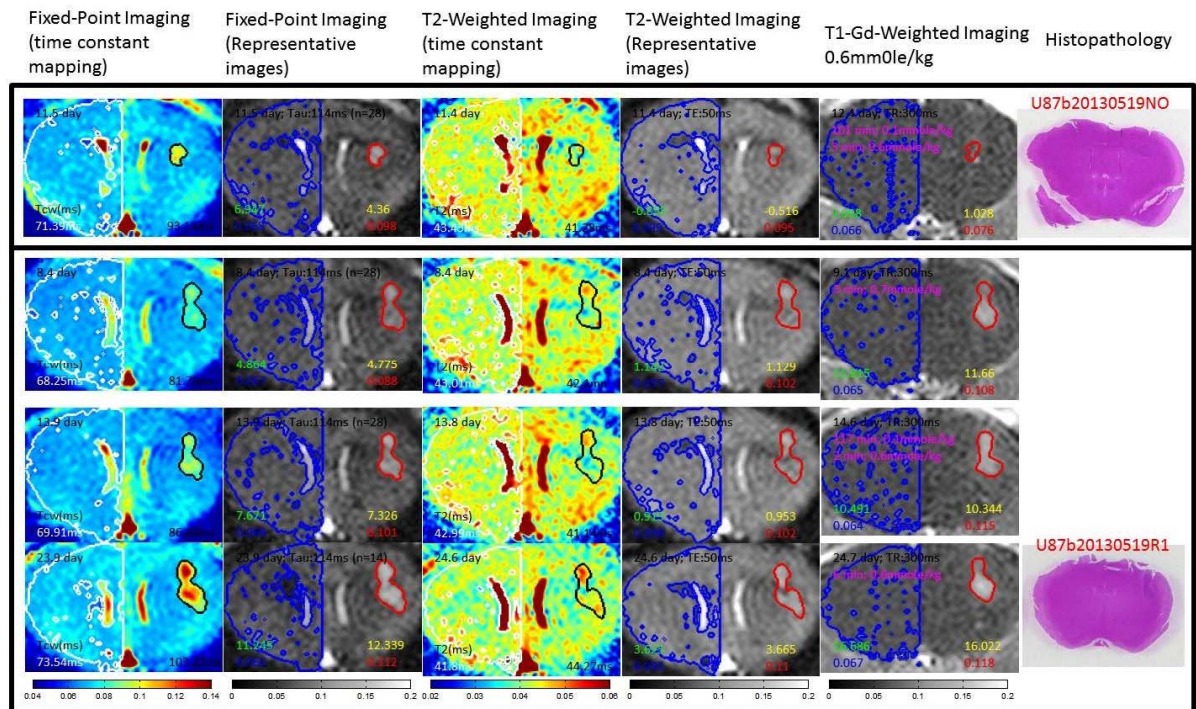

Fig. 2: Representative results from 5 mice. While T2 parameter images (3rd column), T2-weighted images (4th column), and T1-Gd-weighted images (5th column) could not successfully locate the early GBM tumor, our active-feedback fixed-point images (2nd column) and decay constant mapping (1st column) successfully highlight the early GBM tumor with a close correlation with histopathology (6th column).

Reference [1] Science 290, 118 (2001) [2] Magn. Reson. Med. 56, 776 (2006) [3] Magn. Reson. Med. 61, 925 (2009) [4] J. Phys. Chem. B 110, 22071 (2006) [5] Magn. Reson. Med. (submitted) [6] Magn. Reson. Med. (submitted)