Availability for brain ischemic lesions validation from diffusion weighed image difference between single-refocused and twice-refocused spin-echo sequence

Kazuhiro Nakamura[1], Takumi Takahashi[2], Yasushi Kondoh[1], Guoyue Chen[2], and Toshibumi Kinoshita[1]
[1]*Akita Research Institute for Brain and Blood Vessels, Akita, Akita, Japan,* [2]*Akita Prefectural University, Ugohonjo, Akita, Japan*

Introduction: Diffusion weighted imaging with typical single refocused pulsed-gradient spin-echo (SRSE-DWI) sequence is interacted by susceptibility-induced background gradient fields around vessels [1-3]. Apparent diffusion coefficient (ADC) calculated from SRSE-DWI indicates an underestimation of the ADC caused by magnetic susceptibility of vascular networks [1, 2]. The influence of ADC can be reduced by using twice-refocused spin-echo (TRSE-DWI) sequence [2, 3]. Then the difference between SRSE-DWI and TRSE-DWI will indicate cerebral blood volume (CBV) and oxygen consumption from susceptibility change reflected vessel dilatation and deoxy-hemoglobin concentration in brain ischemic lesions. It might be also explicit about the difference of core and penumbra lesions in ischemic stroke. We evaluate the underestimation of the ADC in SRSE-DWI sequences using Monte-Carlo simulations in a vascular model [4] for estimating the availability of brain stroke validation.

Methods: In order to assess the TRSE-DWI and SRSE-DWI, Monte-Carlo (MC) simulations were performed to calculate the signal of molecules diffusing in a vascular network [1, 4]. The brain vasculature radius was assumed Gaussian distribution (mean: 3.3 μm, STD: 2.15μm) as refer to the previous report [4, 5] and total CBV was set to 0.04. The MC algorithm was implemented using homemade C language program performed with debian linux distribution (lenny amd64) in personal computer (CPU: Intel® Core™2 Extreme QX9650). The intra-/ extra-vascular susceptibility difference was set to 0.81×10^{-7} assumed the normal tissue oxygenation level and diffusion constant of the proton was set between 0.6 and 1.0×10^{-5} cm^2/s as mimicked with the brain ischemic lesions. The vessel dilation of each simulation was performed with 1.0, 1.1 and 1.2 times from normal radius and b-value was set to 0, 600, 1200 and 2400 in each simulation. ADC ratio was defined as the ratio of simulated ADC to assumed diffusion constant.

Results and Discussion: Figure 1 shows the relation between b-value and DW signal intensity using SRSE-DWI and TRSE-DWI sequence. The signal intensity was reduced in logarithmic proportional to the b-value as reflected the ADC showing the homemade program was properly simulated. It also indicates ADC calculated from the slope is interacted by susceptibility around vessels in SRSE-DWI, while such effect is reduced in TRSE-DWI. The ADC ratio shown in figure 2 was in almost proportionally reduced to the vessel dilate ratio in SRSE-DW sequence, while the ratio in TRSE-DW sequence remained constant. It indicates the signal difference between SRSE-DWI and TRSE-DWI can be reflected the CBV. It also indicates ADC reduced ratios in SRSE-DW vary in assumed diffusion constant. The difference is especially shown between the diffusion constant of 0.6 and 0.8×10^{-5} cm^2/s in SRSE-DWI. It may indicate the availability for brain stroke validation of core and penumbra lesions.

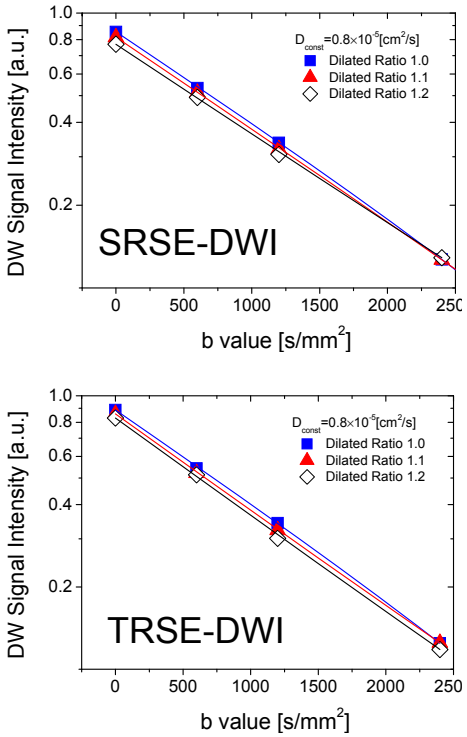

Figure 1. Simulation results of DW signal intensity using SRSE-DWI (upper) and TRSE-DWI (lower) sequences with different vessel dilation levels.

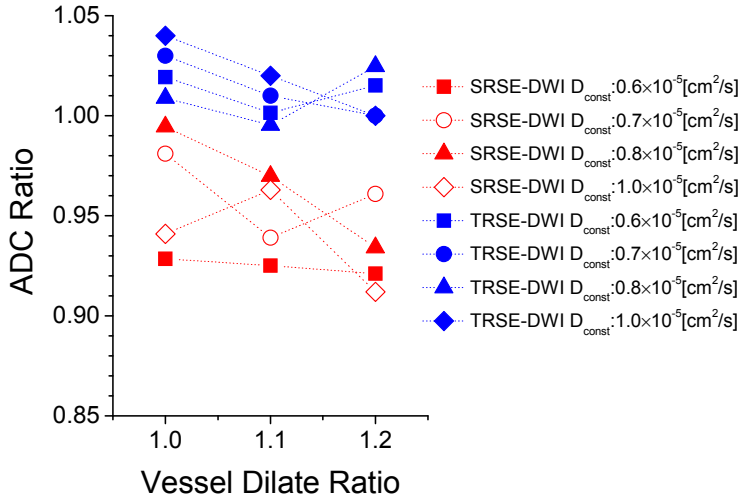

Figure 2. ADC ratio from MC-simulation. Each symbol indicates different D_{cosnt} of assumed diffusion constant. Red and blue points indicate SRSE-DWI and TRSE-DWI simulation results, respectively.

References: [1] A Pampel et al., NMR Biomed 23, 610-618 (2010) [2] J Zhong et al., JMR 95, 267-280 (1991) [3] P Galvosas et al., JMR 166, 164 – 173 (2004) [4] JL Boxermann et al., MRM 34, 555-566 (1995) [5] J Dennie et al., MRM 40, 793-799 (1998)