What is the component that appears in diffusion-weighted imaging at low b values?

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Introduction

The signal from intravoxel incoherent motion (IVIM) appears in diffusion-weighted imaging (DWI) at low *b* values. This low-*b*-value component is believed to reflect capillary blood flow in tissue. However, the quantity of the low-*b*-value component contradicts the data on capillary volume in the literature [1]. To determine the origin of the low-*b*-value component, we investigated the proton density and T2 value of the component.

Materials and Methods

A healthy human volunteer underwent head imaging with a 3-T whole body scanner (Achieva; Philips Medical Systems). Because multislicing complicates the spin history of blood flowing through slices, a single slice (slice thickness, 5 mm) was acquired. To avoid contamination from cerebrospinal fluid, we used single-shot spin-echo EPI with FLAIR (TI = 2650 ms) for DWI; *b* values = 0, 10, 20, 40, 200, 400, 600, 800, and 1000 s/mm^2; field of view (FOV) = 220 × 220 mm^2; and matrix size = 64 × 64. To avoid the influence of T1 values, we used a long repetition time (TR; 10 s) to fully attain longitudinal relaxation. Each DWI experiment was performed with 2 TE values (54 ms and 100 ms) in order to calculate T2 values for the *b* values; this experiment was repeated 10 times. The gray matter (GM) and white matter (WM) areas in the slice were segmented, and the signal intensity for each area was obtained. Next, the so-called perfusion fraction (f) of IVIM was derived [2]; f reflects the quantity of the low-*b*-value components.

Results and Discussion

The low-*b*-value component appeared at *b* values less than 400 s/mm^2. The f values for GM were 8.3% and 8.9% with TE values of 54 ms and 100 ms, respectively, while the f values for WM were 9.5% and 10.2% with TE values of 54 ms and 100 ms, respectively. These values are much higher than the capillary volume fraction, which is less than 2–3% [3] and contains the signal from intravoxel coherent motion (IVCM), which is the blood flow through a voxel. The pseudo diffusion coefficient of IVCM is large, and the signal from IVCM is almost suppressed at *b* values greater than 10 s/mm^2. On subtracting the IVCM component that appeared at *b* values lesser than 10 s/mm^2, the f values for GM decreased to 3.2% and 5.5% with TE values of 54 ms and 100 ms, respectively, while the f values for WM decreased to 4.6% and 7.9% with TE values of 54 ms and 100 ms, respectively. The f value increased with increase in TE, indicating that the low-*b*-value component has a larger T2 value than does the tissue component that appears even at higher *b* values. The T2 values at low-*b*-values, i.e., lesser than 400 s/mm^2, were prolonged (Fig. 1). To quantify the true volume fraction, the f value should be extrapolated to the f value at TE = 0, and MR-visible proton density [4] should be taken into account in this calculation; the true volume fraction was calculated as 1.2% for GM and 1.5% for WM. Using these volume fractions of the low-*b*-value component, the T2 values of the component were calculated as 500 ms for GM and 370 ms for WM. These T2 values are much larger than those for blood [5]; in addition, our results indicate that the f values for WM are larger than those for GM, and this contradicts the results of published studies, which indicate that the capillary blood volume in GM is larger than that in WM. Therefore, the low-*b*-value component does not reflect capillary blood flow. The low-*b*-value component has a larger T2 value than does blood, and this component exhibits IVIM. Because the hydrostatic pressure and osmotic pressure in capillaries drive interstitial fluid flow, which has a large T2 value, we suggest that interstitial fluid mainly contributes to the low-*b*-value component.

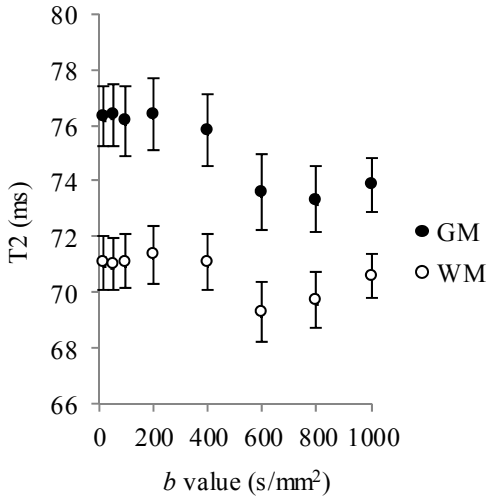

Figure 1 T2 values versus *b* values.
The error bars represent the standard error of the mean.

Conclusion

The low-*b*-value component that appears in DWI may reflect interstitial fluid rather than capillary blood flow.

References

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