Investigation of Efficacy of Depicting Deep Vein Thrombus (DVT) using Diffusion-Weighted Imaging (DWI) and Fresh Blood Imaging (FBI) Venography

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PURPOSE

Deep vein thrombosis (DVT) has become a well-known cause of pulmonary thromboembolism, as an economy-class syndrome. With increasing incidence of DVT, an efficient and non-invasive imaging technique is clinically desired. A non-contrast MRA technique, Fresh Blood Imaging (FBI), allows depiction of veins by acquiring data during systole [1]. The purpose of this study is to clarify the fundamental difference between DWI and FBI in terms of efficacy to depict thrombus of various stages using a viscosity phantom and freshly withdrawn blood.

MATERIALS and METHODS

A paper clay phantom containing x-ray iodine contrast agents (viscosity: 2.9, 4.5, 6.1, 7.0, 13.6 mPa*s 37degC) was prepared to study the effect of viscosity. To optimize DWI and FBI, various sizes of syringe phantoms (0.5, 1.0, 1.5, 2.0 cm in diameter) were used to acquire images with various b factors. To mimic the DVT, freshly withdrawn blood from 8 volunteers (5 males and 3 females; ages 26 to 54 years; mean age 36 years) was used for the experiments. Both the viscosity phantom and blood samples (coagulated blood after 2 days) underwent the DWI and FBI experiments to study the effect of viscosity, ADC value, DWI and FBI signal intensities, T1 and T2 values, and the relationship between a change in b-factors and DWI signal intensity. In addition, the change in DWI, ADC, FBI signal intensity, and T1 and T2 values of the blood samples were investigated over the time course. All experiments were performed using spin-echo type EPI for DWI and 3D half Fourier FSE for FBI venography on a 1.5T clinical imager with a QD head coil.

RESULTS and DISCUSSION

Figure 1 shows SNR values for the DWI images with various b values and FBI images. As the b value increased, the SNR of DWI decreased. Based on the depiction of small size phantoms, the b value of 400 s/mm^2 was selected. In the iodine phantom experiment as shown in Fig. 2, as viscosity increased in all values of ADC, DWI, FBI, T1 and T2 decreased. The blood clot measured the lowest ADC value but high signal intensities were evident in the DWI and FBI images. The low ADC in the blood clot can be due to high viscosity; however other effects such as molecular diameters of fibrin and hemoglobin may be involved. The high signal intensities of the DWI images for the blood clot can be explained due to viscosity and T2 shine-through effects. In the study of the varying b-factors vs. DWI, as the b-factor increased, the DWI signal intensities of iodine phantoms decreased; however, the blood clot showed less of a decrease (Fig.3). The reason for the decrease in signal intensity on the DWI images of the blood clot can be explained by lower ADC values associated with a blood clot when compared to iodine phantoms. From a Stokes-Einstein relationship [2], the iodine phantom is affected by viscosity and the coagulated blood is affected by viscosity and molecular diameters (fibrin and hemoglobin), resulting in lower ADC value. For the chronological change in blood over time course, signal intensity of FBI maintains a high signal and gradually decreases over time, which correlates with T2. Thus, FBI basically follows the T2 image. On the other hand, the DWI signals of 8 volunteers were varied from the time of blood withdrawn through about 6 hours post-withdrawal, however, the high signal intensity on DWI images (low ADC) was observed from 6 hours to 4 days in all volunteers. The early stage of various ADC and DWI changes in volunteers can be attributed to the increase in viscosity due to coagulation of blood and fibrin appearance. In addition, loss of signal in DWI images could be due to organization of thrombus, change in proteins, destruction of red blood cells, change in hemoglobin, etc. Figure 4 shows typical fusion images of DWI and FBI venography, acquired on a 1.5T clinical imager.

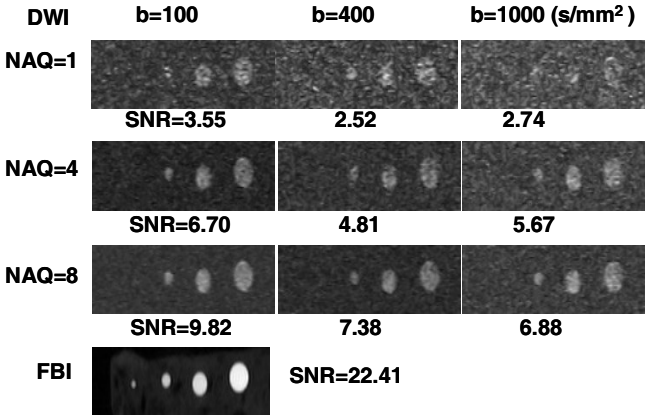

Fig.1 DWI and FBI images of a phantom (viscosity=10.6mPa.s)

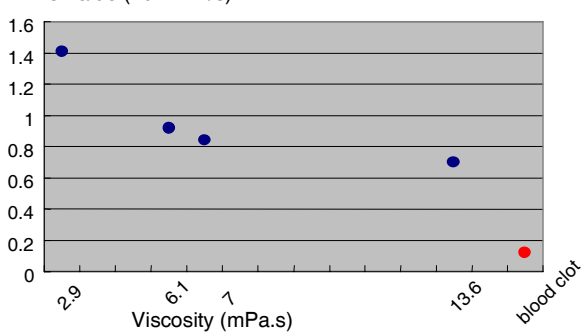

Fig. 2 Relationship of ADC and viscosity

CONCLUSION

The period of high DWI depiction of thrombus is relatively short, whereas the high signal intensity of FBI lasts for a longer period of time before diminishing. Fusion images combining DWI with ADC maps and FBI venography, provides a better depiction of a freshly formed thrombus. The result of the high signal intensities in DWI and FBI images can be related to the viscosity of thrombus and other components of the blood.

REFERENCES

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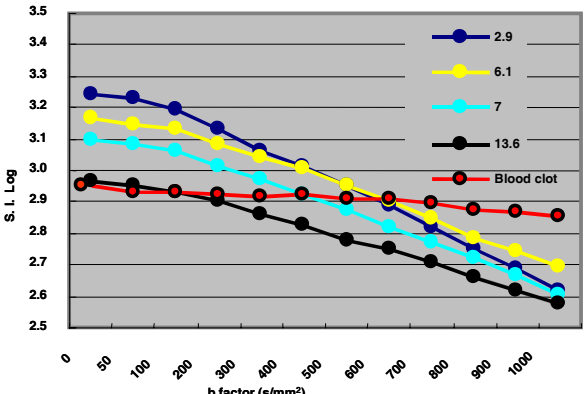

Fig.3 Signal intensity of DWI vs. b value.

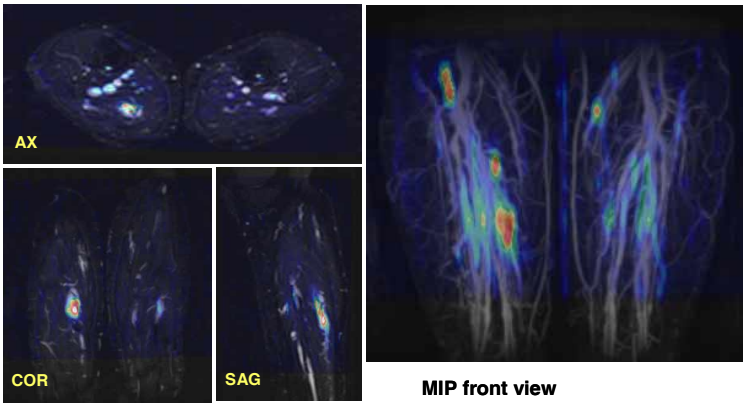

Fig. 4Typical fusion images of DWI and FBI.