Intravoxel Incoherent Motion Diffusion-weighted Imaging in Pediatric Abdominal Tumor

Yanqing Xu[1], Li Wang[1], Zhongwei Qiao[1], and Ed X. Wu[2]

[1]*Department of Radiology, Children Hospital of Fudan University, Shanghai, China,* [2]*EEE of Department, Hong Kong University, Hong Kong, China*

INTRODUCTION: Intravoxel Incoherent Motion (IVIM) Diffusion-weighted magnetic resonance Imaging (DW-MRI) is a sensitive method to visualize the molecular Brownian motion of water (true diffusion) and the microcirculation of blood (pseudodiffusion or perfusion-related diffusion) in biologic tissue [1, 2]. The true diffusion coefficient (D), blood pseudodiffusion coefficient (D*), perfusion fraction (f), determined from DW-MRI on the basis of the IVIM theory have been investigated in adult abdominal organs and tumors [3-5]. Generally, perfusion contributes to the ADCs of abdominal organs and abdominal tumors. The D and f values are useful for the characterization of the tumors. Little was known about the perfusion-related diffusion and true diffusion in pediatric abdominal tumor. This study aims to investigate the D, D* and f in pediatric abdominal tumors by using IVIM DW-MRI.

MATERIALS AND METHODS: **Subject:** This study was approved by the appropriate ethics committee, and written informed consent was obtained. Seventeen children were enrolled in this study, including 10 boys and 7 girls, age from 9 Month to 8 years. DW-MRI was performed before the surgery operation. Children less than 4 year were sedated with oral 10% chloral hydrate during MR scan. The histologic diagnosis was reviewed after the surgery. **MRI Protocol:** All MRI scans were acquired utilizing the Siemens Avanto 1.5 T scanner with a phased array body coil. T2W were acquired using respiratory-gated turbo spin echo, repetition time (TR) > 3630ms, echo time (TE) = 102ms, field of view (FOV) = 250 x 250 mm2 ~ 350 x 350 mm2, slice thickness =5mm, acquisition matrix = 256 x 256. DW imaging was performed in axial slices covering the liver and tumor using respiratory-gated single-shot spin-echo EPI (SE-EPI) with 6 b-values (0, 50, 200, 600, and 800 sec/mm2) and three diffusion gradient directions, TR > 3600ms, TE = 79ms, FOV = 250 x 250 mm2 ~ 350 x 350 mm2, acquisition matrix = 256 x 256, slice thickness = 5mm and number of averages (NEX) = 1. After the DW sequence, Gd-DTPA enhanced T1W was performed to determine the enhancement of tumors. **Data Analysis:** All DW images were analyzed on the Siemens MR Workstation and fitting in MatLab. A region of interest (ROI, large than 10 cm2) was defined to measure signal intensity (SI) at all b values in the tumor and the right lobe of liver. Care was taken to avoid the necrosis tissue in the tumor. The same ROI was used to measure the apparent diffusion coefficient (ADC) on ADC map generated on the Workstation. The true diffusion, D was estimated by using only b values greater than 200 sec/mm2, with a simple linear fit equation: SIb/SI0 = exp (-b x D) [3]. D* and f were estimated by fitting with the IVIM bi-compartmental model: SIb/SI0 = (1-f) x exp (-b x D) + f x exp (-b x D*) with a least-square nonlinear fitting in MatLab. All data were expressed as mean ± SEM. The D, D*, f and ADC in the livers and tumors were compared with One-way ANOVA test. $P < 0.05$ was considered as statistical significant.

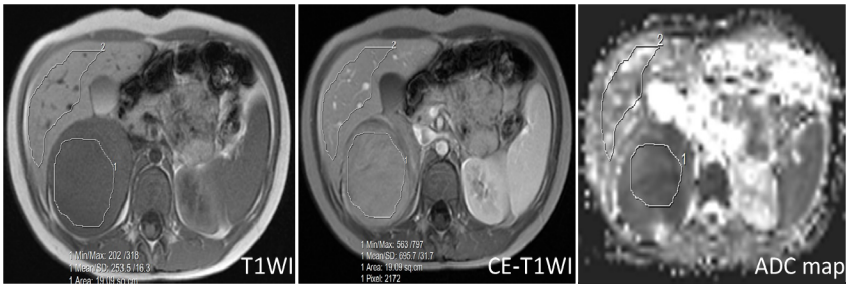

Fig.1 TWI, Gd-DTPA enhanced T1W image and ADC map in a child with neuroblastoma.

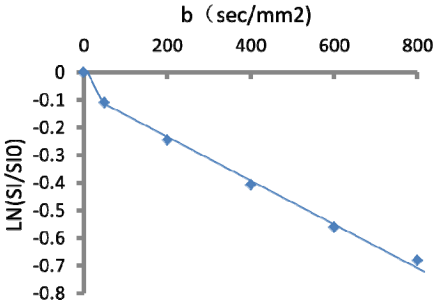

Fig.2 LN(SI/SI0) versus b values curve in a child with neuroblastoma.

RESULTS: In 17 patients, there were 9 neuroblastoma (NB), 4 Wilms's tumor (WT), 1 renal rhabdoid tumor, 1 terotoma, 1 lymphoma and 1 hepatoblastoma, which were identified by pathological analysis. Fig.1 showed a typical TWI, Gd-DTPA enhanced T1W image and ADC map in a child with neuroblastoma. Fig.2 showed a typical bi-exponential DW signal decay in a child with neuroblastoma. Fig. 3 showed the mean ADC, D, D* and f in neuroblastoma and Wilms' tumor in patients. The differences in ADC, D, D* and f in these two tumors were not significant. There were no differences in ADC, D, D* and f of livers in these two groups. In the hepatoblastoma, ADC, D, D* and f were $0.998*10^{-3}$ mm2/s, $0.802*10^{-3}$ mm2/s, 55.8 $*10^{-3}$ mm2/s, and 18.9%, respectively. In the terotoma, ADC, D, D* and f were $1.500*10^{-3}$ mm2/s, $1.132*10^{-3}$ mm2/s, 25.9 $*10^{-3}$ mm2/s, and 33.4%, respectively. In the lymphoma, ADC, D, D* and f were $0.558*10^{-3}$ mm2/s, $0.412*10^{-3}$ mm2/s, 33.3 $*10^{-3}$ mm2/s, and 18.1%, respectively..

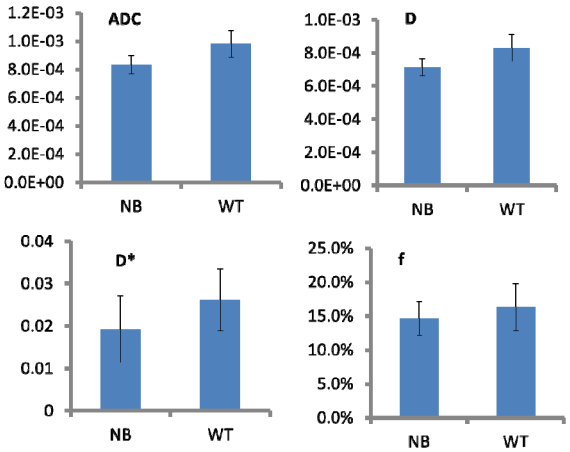

Fig.3 Mean of ADC, D, D* and f in neuroblastoma (NB) and Wilms' tumor (WT) in patients. The differences in ADC, D, D* and f in these two tumors were not significant. (Units are mm2/s in ADC, D and D*.)

DISCUSSIONS: The results of this study indicated that the IVIM DW MRI was feasible in pediatric liver and abdominal tumors. Our results showed that there were no difference in ADC, D, D* and f values between neuroblastoma and Wilms' tumor. Neuroblastoma and Wilms' tumor are common malignant tumors in children. These two tumors showed a lower ADC, D and f compared to the terotoma (common benign tumor in children), but they presented the similar D* values. The hepatoblastoma (malignant tumor in the liver) had a low ADC and D, but a high D* and f, which was comparable to its high blood flow. The lymphoma (malignant tumor) had a low ADC, D, which was possibly due to a high density of tumor cells. But we observed a high D* and f values in lymphoma, which was similar to the values in the neuroblastoma and Wilms' tumor.

CONCLUSION: IVIM DW MRI is a non-invasive method to evaluate pediatric abdominal tumors. Perfusion-related diffusion was observed in malignant and benign tumors; however there was a low D in malignant tumors compared to benign ones. The D and f values are useful for the characterization of pediatric abdominal tumor.

REFERENCES:

1. Lebihan D, et al. Radiology 1986; 161(2): 401-407. **2.** Lebihan D, et al. Radiology 1988;168(2): 497-505. **3.** Luciani A, et al. Radiology. 2008; 249(3): 891-9. **4.** Döpfert J, et al. Magn Reson Imaging. 2011 Oct; 29(8):1053-8. **5.** Chandarana H, et al. Invest Radiol. 2011 May; 46(5):285-91.