Diffusion-Tensor MR imaging of the kidney at 3.0 and 1.5 tesla

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Introduction Diffusion-weighted(DW) MR images allow quantitative measurement of water diffusion using apparent diffusion coefficient(ADC) value(1). In addition to the water diffusion, we can also measure anisotropy of water movement caused by the presence of axons, muscle fibers or vasculature by using Diffusion-tensor(DT) MR imaging . To estimate diffusion anisotropy, fractional anisotropy (FA) is commonly used. It can provide valuable information about the microstructure and pathophysiology of tissues that is not available from conventional imaging and has been prevailed (2). This technique has now become widely used for several organs, including liver, heart, kidney, prostate and muscle (3)(4)(5). However, DTI of abdominal organ was challenging because of respiratory motion. Previous reports relied on breath-holding but it limits image acquisition time and thus limit signal to noise ratio. Recently, High-field 3.0 tesla(T) MRI imager has become frequently used in neurological imaging, and several study on body 3.0T MRI reported favorable result at 3T(6). As for brain, diffusion tensor MR imaging at 3.0T has been reported to provide better SNR despite the severe geometric distortion. It is expected that DTI of the abdominal organ including kidney can be improved by using a 3T magnet, but there is no preceding study on DTI of the kidney at 3T. In this study, we aimed to improve the SNR by employing respiration-triggered scans and 3.0T imagers.

Material and Methods 1)**Study population:** Study population consists of 16 healthy volunteers (age 22-41 y.o., mean 30.6 y.o.). Exclusion criteria were previous renal disease, abnormal findings of the kidney on MR imaging. The subject with poor MR image quality so as not to allow measurement of FA or ADC values was also excluded from the analysis (1/16 cases). **2)MR scanning protocol:** MR images were obtained with a 1.5-T magnet unit (Symphony, Siemens) and a 3.0-T magnet unit (Trio, Siemens) using a phased-array coil. After axial and coronal HASTE scans as a localizer of kidney, DT imaging was obtained using respiration triggered acquisition (trigger delay 100msec, respiratory phase expiratory). The timing of trigger delay was determined after initial analyses for optimum delay. Following imaging parameters are used for both 1.5 and 3.0T scanners; TR =2000 msec, TE=74 msec, slice thickness=3mm, slice number 5, b-values 0 and 400 s/mm, the number of signal average 3, base resolution 128, SENSE factor (Grappa) 2, band width 2056(Hz/Pz), FOV 320 mm. **3)Image Analysis and Statistical analysis** The measurement of FA and apparent diffusion coefficient (ADC) value was obtained using DtiStudio software, version 2.3 (H. Jiang, S. Mori; Johns Hopkins University, mri.kennedykrieger.org). For regions of interest (ROI) placement, one of five slices was selected that contains maximum area of kidney substance. The planes with renal vessels were avoided to prevent flow related artifact. Two ROIs were placed over the cortex and medulla each on upper pole and lower pole. The same ROIs were used for both ADC and FA measurements. Statistical analyses were performed to evaluate the difference in ADC value and FA using student-t test.

Result One subject was deleted from the analysis because of the poor image quality that did not allow taking ROI. In total, 15 participants were included in the study. The value of FA and ADC was shown on table 1. The FA and ADC values from the two magnets were almost the same(Table). However, there were significant differences in FA in medulla ($p<0.01$), ADC value in both cortex ($p<0.01$) and medulla ($p<0.01$). The difference of the FA value between cortex and medulla was significant ($p<0.01$) but not significant in ADC value. The standard deviation of FA and ADC values in 3T magnet was smaller than that of 1.5T magnet, but the difference was not significant ($p=0.18$ in FA of cortex, $p=0.40$ in ADC value of cortex)

Discussion 3T MR magnet, which is initially motivated by specialized research applications such as functional neurological imaging, are now being equipped with body surface coil arrays (6). To the best of our knowledge, there is no report to evaluate FA of the kidney on 3.0T magnet using respiration triggered acquisition.

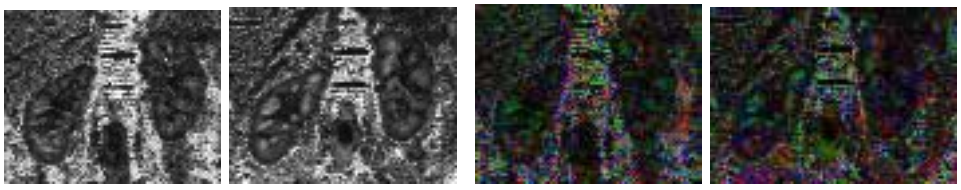
Our results indicated high success rate (15/16) of respiration gating to perform kidney DTI. This significantly reduces burden to patients and allows us to use longer scanning time, thus, improving SNR. In this study there is a possibility that our quantification results are contaminated by a small amount of motion artifacts. In the future, incorporation of navigator echoes that are wildly used for cardiac imaging could further enhance the robustness to the motion (7). We expect that the employment of the respiration gating and higher magnetic field strength will effectively improve SNR and image resolution of kidney DTI studies.

Our result, in which FA and ADC of renal cortex and medullawere significantly higher in the image obtained by the 3T imager, was speculated to be due to better SNR of 3T imager. In addition, the standard deviation of FA and ADC value tended to be smaller in images from the 3T imager, although the difference was not large. FA and ADC value of cortex and medulla obtained in our study was almost the same with those reported before (8)(5). FA value of medulla was lower than that of cortex as mentioned in previous report. The medulla of the kidney is anisotropic because of the radial orientation of its structure (5).

It is of great interest to apply this technique to various types of kidney diseases such as early detection of diffuse renal disease that is difficult to detect by morphological imaging

In conclusion, we demonstrated feasibility of respiration gating of kidney DTI. Improved SNR by a high-field (3T) magnet is also shown. Quantification results of FA and ADC agreed with previous publications..

FIG1 FA map



1.5T 3T 1.5T 3T

Table		1.5T	3.0T
FA	cortex	0.140±0.033	0.151±0.027
	medulla	0.418±0.048	0.494±0.044
ADC	cortex	2.201±0.112	2.458±0.09
($x10^{-3}$)	medulla	1.901±0.108	2.082±0.084
difference	FA	0.278	0.343
(M-C)	ADC	0.299	0.376

M=medulla, C=cortex

Representative case is presented in figure 1.

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