362
ELSEVIER
Available online at www.sciencedirect.com
SCIENCE DIRECT
JNMU
Journal of Nanjing Medical University, 2008, 22(6):362–365
www.elsevier.com/locate/jnmu
Research paper

Value of Apparent Diffusion Coefficient(ADC) of Diffusion eighted Magnetic Resonance Imaging in Common Renal Disease Diagnosis

Yuelang Zhang, Xingwang Sun*, Guangnan Quan, Yongqian Qiang, Chenxia Li

Department of medical imaging, the First Affiliated Hospital, Medical school of Xi' an Jiaotong University, Xi' an 710061,Shaanxi Province, China

Received 2 October, 2008

Abstract

Objective: To find the value of the apparent diffusion coefficient (ADC) of diffusion weighted magnetic resonance imaging of common renal diseases. **Methods:** There were 30 healthy subjects and 81 patients with renal lesions (56 cases of renal carcinoma, 18 lesions of 12 cases of renal angiomyolipoma, and 21 lesions of 13 cases of renal cysts). Conventional magnetic resonance imaging and diffusion weighted magnetic resonance imaging were carried out. We measured the average ADC value of the renal lesions and normal kidneys. ADC maps from different b values were generated by a statistical package. **Results:** The ADC values of normal kidneys with three different motion-probing gradients(b=500, 800, 1000 sec/mm^2) were $2.78 \pm 0.14 \times 10^{-3}mm^2s^{-1}$, $2.45 \pm 0.13 \times 10^{-3}mm^2s^{-1}$, $2.13 \pm 0.14 \times 10^{-3}mm^2s^{-1}$, respectively. The ADC values of renal cell carcinoma with three different motion-probing gradients(b=500, 800, 1000 sec/mm^2) were $1.63 \pm 0.14 \times 10^{-3}mm^2s^{-1}$, $1.31 \pm 0.18 \times 10^{-3}mm^2s^{-1}$, $1.07 \pm 0.15 \times 10^{-3}mm^2s^{-1}$, respectively. Among the renal cell carcinoma, the ADC value of clear cell type were $1.67 \pm 0.09 \times 10^{-3}mm^2s^{-1}$, $1.36 \pm 0.13 \times 10^{-3}mm^2s^{-1}$, $1.15 \pm 0.14 \times 10^{-3}mm^2s^{-1}$,respectively; the ADC values of granular cell type were $1.59 \pm 0.19 \times 10^{-3}mm^2s^{-1}$, $1.25 \pm 0.22 \times 10^{-3}mm^2s^{-1}$, $0.97 \pm 0.12 \times 10^{-3}mm^2s^{-1}$, respectively. The ADC values of renal angiomyolipoma with three different motion-probing gradients(b=500, 800, 1000 sec/mm^2) were $0.88 \pm 0.08 \times 10^{-3}mm^2s^{-1}$, $0.63 \pm 0.07 \times 10^{-3}mm^2s^{-1}$, $0.43 \pm 0.04 \times 10^{-3}mm^2s^{-1}$, respectively. The ADC values of renal cystic lesions with three different motion-probing gradients(b=500, 800, 1000 sec/mm^2) were $3.73 \pm 0.18 \times 10^{-3}mm^2s^{-1}$, $3.44 \pm 0.13 \times 10^{-3}mm^2s^{-1}$, $3.09 \pm 0.21 \times 10^{-3}mm^2s^{-1}$, respectively. Statistically significant differences exists between the ADC values of normal kidney, renal carcinomas, renal angiomyolipomas and renal cysts when the b value is the same. Among the different cell types of renal carcinomas, the ADC value of granular cell carcinoma is lower than that of clear cell carcinomas. **Conclusion:** It is of benefit in diagnosing and distinguishing between benign and malignant renal tumors to know the ADC values in diffusion weighted magnetic resonance imaging. Furthermore, these values help to know the internal structure of the tumor and the tumor typel, which is helpful to the treatment and in predicting the patient's prognosis.

Key words: Diffusion weighted imaging; apparent diffusion coefficient; renal cell carcinoma; renal angiomyolipoma; Renal cyst

INTRODUCTION

Diffusion weighted imaging(DWI) is one of many functional magnetic resonance imaging(fMRI) techniques. It is the only way to conduct water molecule diffusion imaging in vivo. DWI reflects the diffusion properties of water molecules in an organism and appraises the random motion of the water molecule, providing spatial and structural information about the tissue. The apparent diffusion coefficient(ADC) facilitates quantitative analysis of pathological changes of responding tissues. Its application is relatively mature in the central nervous system but exploratory in the abdomen and various internal organs[1-6]. Few studies have been carried out with regard to the kidney. This study aims to probe into the value of ADC in the evaluation of common renal diseases.

SUBJECTS AND METHODS

Subjects

The research subjects included 30 healthy volunteers with normal renal functions and 81 patients with various renal lesions. The normal group had 18 men

*Corresponding author.
E-mail address: sunxingw@163.com

and 12 women aging from 22 to 52 with a median age of 36.5. The patient group had 55 men and 26 women aging from 7 to 79, including 56 cases of renal carcinoma, 18 lesions of 12 cases of renal angiomyolipoma, and 21 lesions of 13 cases of renal cysts. The patients with renal carcinoma were confirmed by operation and pathology, including 33 cases of clear cell carcinoma, 19 cases of granular cell carcinoma, 3 cases of mixed carcinomas of clear cells and granular cells, and 1 case of spindle cell carcinoma. Among the patients with renal angiomyolipomas, 8 cases were proved by operation and pathology; 4 underwent comprehensive diagnosis according to clinical data, B-ultrasound, plain CT scan, enhanced CT scan and plain MR scan with follow-up and observation. Among the patients with renal cysts, 1 case was confirmed by operation, 2 cases were confirmed by biopsy, and 10 cases were confirmed by clinic data, CT scan, MR scan, and comprehensive diagnosis.

MR Imaging

Philips Gyroscan Intera 1.5T superconductive MR imaging unit was used with SENSE software. Phased array body coils compatible with the SENSE consist of four units. For morphologic evaluation of the kidneys, transverse T1WI, T2WI, T1W/WATS and sB-TFE scanning were performed during the patient's suspension of respiration. DWI were obtained by using sDW/ssh sequence. The relevant parameters are as follows: rapid imaging model: EPI; diffusion model: SE; excitation mode: single shot and isotropy; number of b value: 2; maximum b value: 500/800/1000, TE 56/64/68ms, TR 1000ms,THK 6.0/1.0, FOV 375~425, RFOV 70%, NSA 6; trigger respiratory gating was used for scanning during free breathing; The delay time was 100-300ms; the scanning time is 52-97s.

Data collection

Diffusion weighted data software provided by Philips was used to remake ADC maps from diffusion weighted images with 500, 800, and 1000 s/ mm^2 as the b values. The ADC value can be measured directly from the ADC map. In measuring the ADC value of the normal kidney, an elliptical region of interest(ROI) can be adopted for measurement in the renal hilum section on both sides to obtain the mean value, avoiding the kidney's collecting system, tissue of the renal sinus, and artifact. In measuring renal cell carcinoma, the central section of the lesion was chosen, which covers the main portion of tumor(***Fig. 1***). The outline would be drawn by hand to exclude the necrosis(***Fig. 2***). As renal angiomyolipoma and renal cysts have explicit outlines on the whole, subround ROI in the central section of the lesion was chosen for measurement(***Fig. 3,4***).

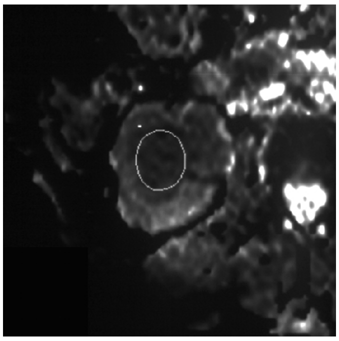

Fig. 1 ADC images of right granular cell renal carcinoma in 45-year-old man(b = 800 s/ mm^2). ROI of the parenchyma of the tumor. the value of ADC is $1.126 \times 10^{-3} mm^2 s^{-1}$

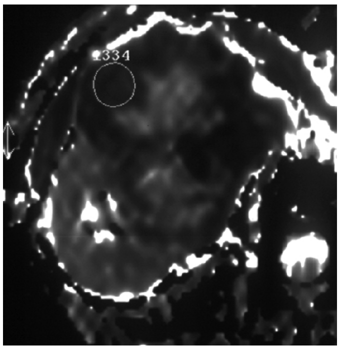

Fig. 2 ADC images of right clear cell renal carcinoma in 41-year-old man(b=800 s/ mm^2). ROI is carefully put in the tumor to avoid the necrosis of the tumor. The value of ADC is $1.468 \times 10^{-3} mm^2 s^{-1}$

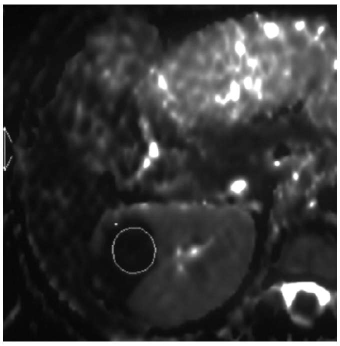

Fig. 3 ADC images of right renal angiomyolipoma in a 37-year-old man(b=800 s/ mm^2). ROI includes as many tumors as possible . The value of ADC is $0.726 \times 10^{-3}\ mm^2 s^{-1}$.

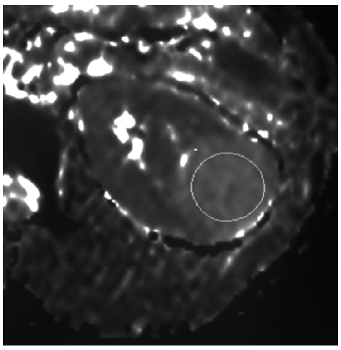

Fig. 4 ADC images of left renal cyst in 41-year-old man(b=800 s/mm^2). ROI includes the major part of the cyst. The value of ADC is $3.318 \times 10^{-3} mm^2 s^{-1}$.

Statistical analysis

The statistics software SPSS 16.0 was used for statistical analysis $\bar{x} \pm s$. indicates the mean value and standard deviation. T test and one-way ANOVA were included for data analysis. P values of less than 0.05 were considered to indicate statistically significant differences.

RESULTS

ADC values of normal kidney, renal carcinoma, renal angiomyolipoma and renal cyst were compared in cases with b values of 500, 800, and 1000 s/ mm^2.. All group mean values are different from each other at the same b value,$P < 0.05$(***Table 1***). Among the different cell types of renal carcinoma, the mean ADC value shows statistical difference between clear cell carcinoma and granular cell carcinoma. And the mean ADC value of granular cell carcinoma is significantly lower than that of clear cell carcinoma at higher b value(***Table 2***).

Table 1 **Comparison of ADC values of normal kidney, renal carcinoma, renal angiomyolipoma, and renal cysts**

	normal kidney (n = 30)	renal carcinoma (n = 56)	renal angiomyolipoma (n = 18)	renal cysts (n = 21)
500 s/mm^2	2.78 ± 0.14	1.63 ± 0.14	0.88 ± 0.08	3.73 ± 0.18
800 s/mm^2	2.45 ± 0.13	1.31 ± 0.18	0.63 ± 0.07	3.44 ± 0.13
1000 s/mm^2	2.13 ± 0.14	1.07 ± 0.15	0.43 ± 0.04	3.09 ± 0.21

Compared with the same b valve, P = 0.000, the unit of ADC is × 10^{-3} mm^{2}s^{-1}.

Table 2 **Comparison of ADC values between Clear cell carcinoma and granular cell carcinoma**

	Clear cell carcinoma (n = 33)	granular cell carcinoma (n = 19)	P
500 s/mm^2	1.67 ± 0.09	1.59 ± 0.19	0.048
800 s/mm^2	1.36 ± 0.13	1.25 ± 0.22	0.031
1000 s/mm^2	1.15 ± 0.14	0.97 ± 0.12	0.000

the unit of ADC is × 10^{-3} mm^{2}s^{-1}

DISCUSSION

The present study conducted DWI of common space occupying lesions, including renal carcinoma, renal angiomyolipoma, and renal cysts. Table 1 indicates that ADC values of renal carcinoma, renal angiomyolipoma and renal cyst were significantly different from each other in cases of the same b value. The mean ADC value of renal cysts was the largest, renal carcinomas the second and renal angiomyolipoma the smallest. The mean ADC value of solid tumors is significantly less than that of normal tissue, which is consistent with previous studies[7-11]. The possible reason is that the arrangement of tumor cell is compact compared with normal tissue. Close clearance between the cells impedes the dispersion of water molecules. Another reason is that tissue of renal carcinomas has an insufficient supply of blood compared with normal kidney tissue.

The ADC value reflects the components of tumor to some extent. The region with the smallest ADC value is generally the place with the largest number of tumor cells. Rapid growth of the malignant tumor cells and compact arrangement of the cells reduce the clearance and restrain the dispersion of water molecule, thus reducing the ADC value[12,13]. ***Table 2*** indicates that the mean ADC value of clear cell carcinomas is larger than that of granular cell carcinomas. Thus a statistically significant difference exists between ADC values of renal carcinomas of different cell types.

Generally speaking, the more malignant the tumor is, the more atypical the tumor cell is, with larger nuclei, higher nucleus-cytoplasm ratio, and restrained dispersion of water molecules in the cell. Therefore, a theoretical speculation on cell types of renal tumors could be conducted as follows: the clear cell carcinoma is less malignant with relatively better prognosis; its ADC value is relatively large because the cells have lower nucleus-cytoplasm ratio with relatively less obvious atypia and interstitial capillary vessels. On the other hand, a granular cell carcinoma is more malignant, with a poor prognosis; its ADC value is relatively small because the cells show remarkable atypia with large nuclei and interstitial fibrous tissue.

However, there are some cross data among individual cases. Moreover, the sample sizes of our two groups was relatively small. There is a difference between the present study and reports in the literature. Squillaci and Manenti etc[7,10]. found that there was no significant difference between ADC values of different cell types, although ADC values of renal tumors is related to their histological makeup Therefore, further research is needed.. As for mixed carcinoma and spindle cell carcinoma, there is no statistical analysis or conclusion due to their small sample size. By measuring the ADC value of tumor parenchyma, we can know the internal structure of the tumor and types of the tumor cell in the main, which could guide clinical treatment and provide an estimate of prognosis.

The most common benign renal tumor is the angiomyolipoma, which consists of smooth muscle, abnormal vessels, and adipose tissue. Typical angiomyolipomas with a lot of adipose ingredient can be diagnosed by conventional MRI[14]. However, it is difficult to distinguish between angiomyolipomas with blood vessel and smooth muscle tissues as the main ingredients and renal carcinomas. As for the present study, DWI is of greater effectiveness than conventional MR. After conducting DWI of 18 foci in 12 cases, we found that the ADC value was dependent on the relative proportions of adipocytes, smooth muscles, and blood vessels in the tumor. The greater the adipose tissue content, the smaller was the mean value of ADC. Adipose content of the 18 foci in the present study varied greatly. Accordingly, the ADC values had a wide range. However, even the ADC value of the focus with the lowest adipose content is outside the range of that of normal kidney and renal carcinoma, so there exists a significant statistical difference between the average ADC value of all the angiomyolipomas and the average ADC value of normal kidneys and renal carcinomas. The possible reasons for the small ADC value are as follows: there are numerous adipose cells in the focus with few water molecules in the cytoplasm; while arrangement of the smooth muscle cells is compact; the abnormal vessels are full of blood with fibrous tissue, ground substance, and even bleeding in the vascular lacuna. The high viscosity restrains the motion of water molecules. Therefore, the ADC values are small regardless of the b value.

The present study finds that DWI is of great value to distinguishing renal carcinomas without obvious signs of infiltration and failure, and angiomyolipoma with blood vessel and smooth muscle tissues as the main ingredients. As for the various kinds of renal cysts, DWI indicates a low signal intensity and ADC shows a high signal intensity as the water molecules disperse freely in the large amount of water inside the cysts. The findings related to the renal cysts are consistent with previous studies.

Compared with conventional MRI, DWI provides more information about pathological changes. Its value has been gradually revealed[15]. However, DWI also has some limitations, such as poor image quality, various kinds of artifacts, and lack of standards for b values[7-11,16]. With improvements in hardware and software and facilities, these limitations can be minimized or overcome, bringing us a wider application of DWI.

References

[1] Warach S,Chien D,Li W,Ronthal M,Edelman RR. Fast magnetic resonance diffusion-weighted imaging of acute human stroke. *Neurology* 1992; 42:1717-23.

[2] Enzinger C, Thimary F, Kapeller P, Ropele S, Schmidt R, Ebner F, *et al.* Transient global amnesia: diffusion-weighted imaging lesions and cerebrovascular disease. *Stroke* 2008; 39:2219-25.

[3] Obenaus A, Ashwal S. Magnetic resonance imaging in cerebral ischemia: Focus on neonates. *Neuropharmacology* 2008; 55:271-80.

[4] Kitajima K,Kaji Y,Kuroda K,Sugimura K. High b-value diffusion-weighted imaging in normal and malignant peripheral zone tissue of the prostate: effect of signal-to-noise ratio. *Magn Reson Med Sci* 2008; 7:93-9.

[5] Youn BJ, Chung JW, Son KR, Kim HC, Jae HJ, Lee JM,*et al.* Diffusion-weighted MR: therapeutic evaluation after chemoembolization of VX-2 carcinoma implanted in rabbit liver. *Acad Radiol* 2008; 15:593-600.

[6] Gu TF, Xiao XL, Sun F, Yin JH, Zhao H.Diagnostic value of whole body diffusion weighted imaging for screening primary tumors of patients with metastases. *Chin Med Sci J 2008;*23: 145-50.

[7] Squillaci E, Manenti G, Cova M, Di Roma M, Miano R, Palmieri G, Simonetti G. Correlation of diffusion-weighted MR imaging with cellular of renal tumors. *Anticancer Res* 2004; 24:4175-9.

[8] Squillaci E,Manenti G,Di Stefano F,Miano R,Strigari L, Simonetti G. Diffusion-weighted MR imaging in the evaluation of renal tumors. *J Exp Clin Cancer Res* 2004;23: 39-45.

[9] Cova M, Squillaci E,Stacul F ,Manenti G, Gava S, Simonetti G, *et al.* Diffusion-weighted MR imaging in the evaluation of renal lesions: preliminary results. *Br J Radiol* 2004; 77:851-7.

[10] Manenti G, Di Roma M, Mancino S, Bartolucci DA, Palmieri G, Mastrangeli R,*et al.* Malignant renal neoplasms: correlation between ADC values and cellularity in diffusion weighted magnetic resonance imaging at 3 T. *Radiol Med* 2008;113: 199-213.

[11] Zhang J, Tehrani YM, Wang L, Ishill NM, Schwartz LH, Hricak H. Renal masses: characterization with diffusion-weighted MR imaging-a preliminary experience. *Radiol* 2008; 247:458-64.

[12] Yoshikawa T, Kawamitsu H, Mitchell DG, Ohno Y, Ku Y, Seo Y, *et al.*ADC measurement of abdominal organs and lesions using parallel imaging technique.*AJR Am J Roentgenol* 2006; 187:1521-30.

[13] Woodhams R, Matsunaga K, Kan S, Hata H, Ozaki M, Iwabuchi K, *et al.* ADC mapping of benign and malignant breast tumors. *Magn Reson Med Sci* 2005;4:35-42.

[14] Pedrosa I, Sun MR, Spencer M, Genega EM, Olumi AF, Dewolf WC, *et al.* MR imaging of renal masses: correlation with findings at surgery and pathologic analysis. *Radiographics* 2008; 28:985-1003.

[15] Low RN, Gurney J. Diffusion-weighted MRI(DWI) in the oncology patient: value of breath hold DWI compared to unenhanced and gadolinium-enhanced MRI. *J Magn Reson Imaging* 2007; 25:848-58.

[16] Thoeny HC, De Keyzer F, Oyen RH, Peeters RR. Diffusion-weighted MR imaging of kidneys in healthy volunteers and patients with parenchymal diseases: initial experience. *Radiology* 2005; 235:911-7.