European Journal of Therapeutics DOI: 10.5152/EurJTher.2019.18058

Original Research

Apparent Diffusion Coefficient Values of Renal Parenchyma in Healthy Adults: A 3 Tesla MRI Study

Hale Çolakoğlu Er

Department of Radiology, Gaziantep University, School of Medicine, Gaziantep, Turkey

ABSTRACT

Objective: In this study, we aimed to measure apparent diffusion coefficient (ADC) values of healthy renal parenchyma using diffusion-weighted imaging (DWI) in a 3 Tesla (3T) magnetic resonance imaging (MRI) device.

Methods: Apparent diffusion coefficient values of right and left renal parenchyma were measured in 87 individuals (64 females, 23 males) from DWIs obtained with a 3T MRI device. In the ADC measurement, bilateral renal parenchymal margins were drawn by the free-hand region of interest (ROI) on DWI (b=600 s/mm^2), and ADC_{mean} values were recorded from ROIs on the ADC map.

Results: The ADC_{mean} value of renal parenchyma was 2.21×10^{-3} mm^2/s and 2.2×10^{-3} mm^2/s for the right and left kidney, respectively. Measured ADC values of the right and left renal parenchyma were highly consistent (Intraclass correlation coefficient (ICC=0.968; confidence interval (CI):[0.952–0.979]). ADC values of renal parenchyma were significantly lower in the group of patients older than or equal to 50 years as compared to the group of patients younger than 50 years (p=0.001). There was no significant difference between females and males in terms of the ADC values of renal parenchyma (p=0.161 for the right kidney, p=0.207 for the left kidney). Measured ADC values of the right and left renal parenchyma were highly consistent (ICC=0.968; CI:[0.952–0.979]). There was a strong negative correlation between ADC values of renal parenchyma and age (r=−0.686, p=0.001 for the right kidney; r=−0.759, p=0.001 for the left kidney).

Conclusion: Apparent diffusion coefficient values are quantitative values obtained by DWI, and it is important to understand the ADC values of normal healthy renal parenchyma in order to interpret ADC values in renal pathologies.

Keywords: Apparent diffusion coefficient, diffusion-weighted imaging, kidney

INTRODUCTION

Diffusion-weighted magnetic resonance (MR) imaging is an imaging method based on detecting the random movements of water molecules (1). In the human body, water is in cells and extracellular compartments. While the water molecules in extracellular media show relatively free diffusion, intracellular molecules exhibit relatively limited diffusion. Different tissues of the body have a characteristic cellular structure and proportions of intracellular and extracellular regions, and they also have characteristic diffusion properties. The relative proportion of water distribution between these compartments varies with pathological processes. For example, in intracellular high-grade malignancies, the intracellular ratio increases, and diffusion is relatively restricted. Diffusion-weighted imaging (DWI) provides qualitative and quantitative information about diffusion characteristics (2).

Diffusion-weighted imaging is an advantageous MR imaging method as it does not involve any contrast agents, and it is a non-invasive method, enabling quantitative assessment as well as qualitative assessment. The apparent diffusion coefficient (ADC) is a quantitative value that enables quantitative measurement on the ADC map obtained from DWI. While DWI has previously been performed on the brain for the diagnosis of acute ischemia, it has also become common in abdominal pathologies, and it is now included as an imaging modality in routine MR examinations in many centers. It greatly contributes to diagnosis in pathologies of abdominal organs such as the liver and pancreas (3, 4). Studies have shown that ADC values have been useful in assessing solid kidney lesions, differentiating between benign and malign kidney lesions and the subtype determination of malign solid masses (5-7).

It is important to understand the ADC values of normal healthy renal parenchyma to interpret ADC values in renal pathologies. Although there have been studies conducted with a 1.5 Tesla MRI device on this subject, the number of studies conducted with a 3 Tesla (3T) MRI device is limited in the literature (8). In this study, we aimed to measure the ADC values of healthy renal parenchyma using DWI with a 3T MRI device.

METHODS

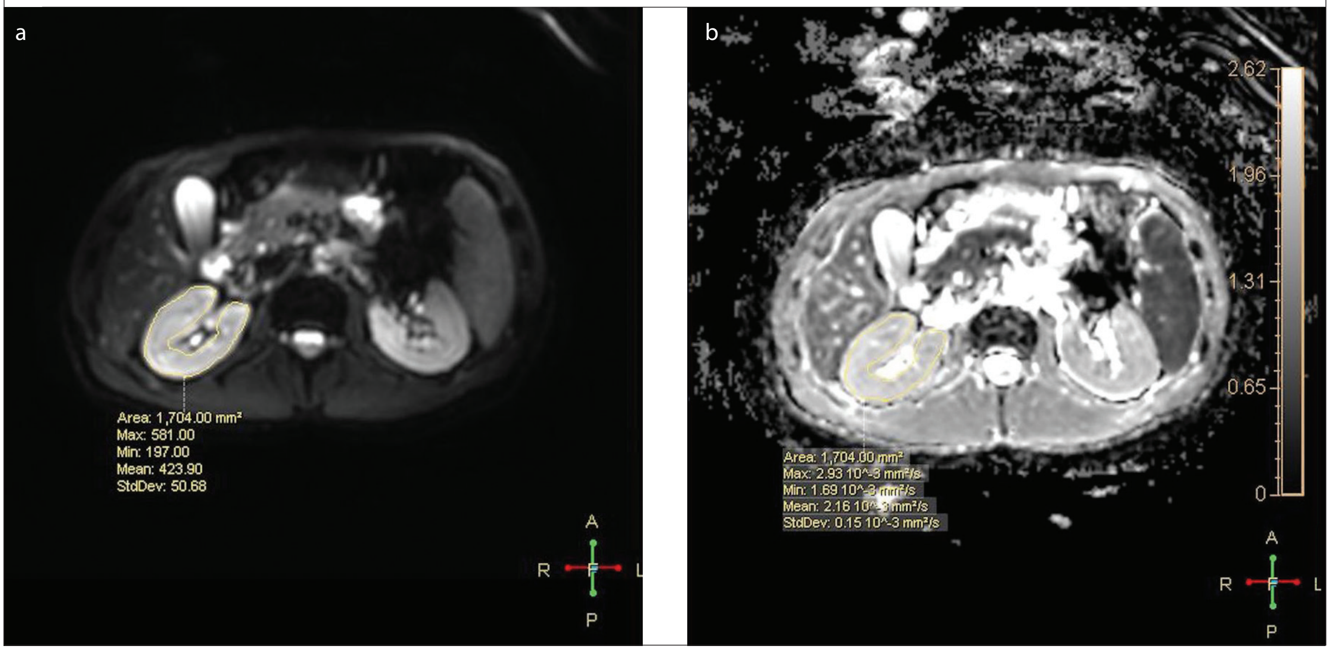
Volunteers without abdominal MRI findings who underwent abdominal MR imaging, including DWI for screening purposes due to other reasons, between August 2017 and August 2018 in the Radiology Department of Gaziantep University, School of Medicine, were included in this retrospective study. Written informed consent was provided by all patients prior to the start of

ORCID ID of the author: H.Ç.E. 0000-0002-5210-734X.

Corresponding Author: Hale Çolakoğlu Er **E-mail:** halecolakoglu83@yahoo.com

Received: 01.11.2018 • **Accepted:** 11.02.2019

Figure 1. a, b. The measurement of renal parenchyma apparent diffusion coefficient (ADC) values of a 40-year-old male. Axial diffusion-weighted image (a) obtained at a b value of 600 s/mm². The ADC map (b) shows that the ADC mean value of the kidney is 2.16×10^{-3} mm²/s



the study, which was approved by Gaziantep University Ethics Committee (decision no. 2018/246).

Patients with a known kidney disease, hypertension, and diabetes were excluded from the study. The MR examination was performed on a 3T MRI device (Ingenia 3.0 T; Philips Healthcare, Best, The Netherlands), as an abdominal MRI that also includes diffusion MRI. MRI sequence parameters were as follows: axial T2-weighted turbo spin echo with fat suppression, gradient echo in phase and in opposed phase with T1 weighting, diffusion-weighted axial images, and contrast-enhanced dynamic T1-weighted imaging. DWI was acquired with b values of 0 and 600 s/mm² and without a contrast agent. Diffusion-weighted sequence parameters were as follows: repetition time/echo time, 1553/61 mS; flip angle, 90°; slice thickness, 5 mm; field of view, 400 x 350 x 270 mm. A diffusion-weighted sequence was obtained at two different b values (b=0 and b=600 s/mm²) with single-shot echo planar imaging in the axial plane. ADC maps were generated automatically by the device.

The final study population was 87 consecutive patients (64 females, 23 males; age range, 19–80 years; mean age, 47 years). The study population was divided into two groups: younger than 50 years, and older than or equal to 50 years, in order to evaluate the relationship between the ADC values of renal parenchyma and aging. There were 52 individuals younger than 50 years, and 35 individuals older than or equal to 50 years.

In the ADC measurement, bilateral renal parenchymal margins were drawn by free-hand ROI on DWI (b=600 s/ mm²), and ADC_{mean} values were recorded from ROIs on the ADC map. Measurements were repeated five times for each kidney, and the ADC_{mean} value was calculated and recorded individually for the right and left kidney. Figure 1 shows the measured ADC values of renal parenchyma.

Statistical Analysis

As descriptive statistics, numerical variables were expressed as the mean±standard deviation, and a confidence interval (CI) of 95% was used. Categorical variables were expressed as a number and percentage. Normal distribution of the data was tested by the Shapiro–Wilk test. The Pearson correlation coefficient was used to evaluate the relationship between the ADC values of renal parenchyma and age. The intraclass correlation coefficient was used to compare the values of the right and left renal parenchyma. Gender and ADC relationship was evaluated with the Student's t test. The Student's t test was used for the comparison of ADC values of the group younger than 50 years, and older than or equal to 50 years. The Statistical Package for the Social Sciences for Windows version 22.0 (SPSS IBM Corp.; Armonk, NY, USA) software package was used for statistical analysis, and $p<0.05$ was considered statistically significant.

RESULTS

The ADC_{mean} value of renal parenchyma was 2.21×10^{-3} mm²/s and 2.2×10^{-3} mm²/s for the right and left kidney, respectively. Measured ADC values of the right and left renal parenchyma were highly consistent (ICC=0.968, CI:[0.952–0.979]). ADC values of renal parenchyma were significantly lower in the group older than or equal to 50 years in comparison to the group younger than 50 years (p=0.001). There was no significant difference between males and females in terms of ADC values of renal parenchyma (p=0.161 for the right kidney, p=0.207 for the left kidney). There was a strong negative correlation between the ADC values of renal parenchyma and age (r=–0.686, p=0.001 for the right kid-

Figure 2. Strong negative correlation between the apparent diffusion coefficient values of the right kidney parenchyma and age (r=−0.686, p=0.001)

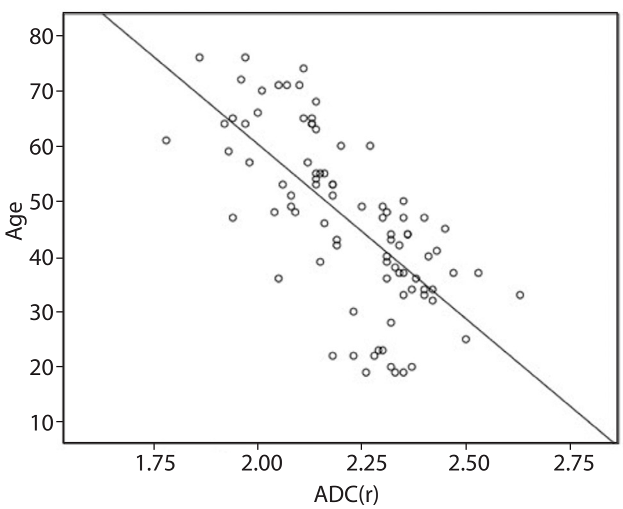
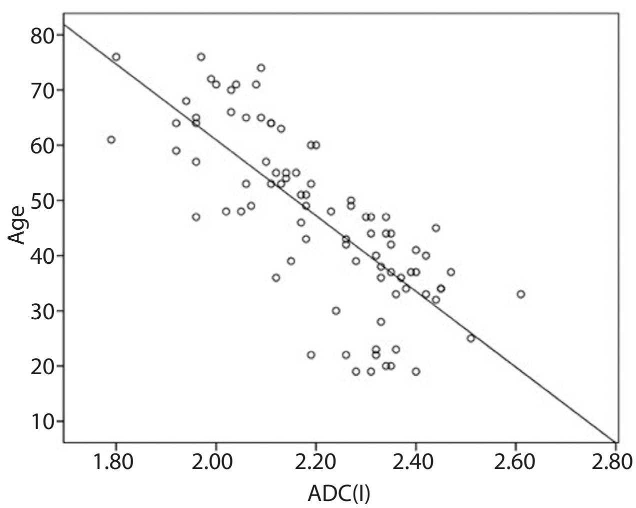


Figure 3. Strong negative correlation between the ADC values of the left kidney parenchyma and age (r=−0.759, p=0.001)



ney; and r=−0.759, p=0.001 for the left kidney). This correlation is shown in Figures 2 and 3.

DISCUSSION

Diffusion-weighted imaging can be used in diagnosing of kidney diseases as of the prenatal period since it is noninvasive and does not require a contrast agent. Including DWI in routine abdominal MRI enables the evaluation of morphological and functional changes together. High ADC values of cystic lesions are useful in differentiating between solid lesions and cystic lesions (9). Necrotic and cystic tumor areas also have significantly lower ADC values as compared to simple cysts (5). In a study conducted by Razek et al. (10), a significant difference was found between the mean ADC values of malignant and benign renal tumors. The authors also reported that using 1.84x10^{-3} mm^2/s cutoff value to predict malignancy had a sensitivity of 89% and specificity of 89%. Diffusion tensor imaging (DTI) is an advanced DWI technique and can be used in many regions of body as other advanced diffusion techniques (11). A study on DTI of the kidney showed that renal fractional anisotropy and renal cortex ADC may be useful to differentiate a diabetic kidney from kidneys of healthy volunteers (12).

Apparent diffusion coefficient values were found to be effective in differentiating between the subtypes of renal cell carcinomas (7, 10). It is possible to distinguish renal oncocytoma from solid renal cell carcinoma RCC using a 1.66 x10^{-3} mm^2/s cutoff value with a 90% sensitivity and 83% specificity (6). In addition, it was also found that DWI was promising in the early diagnosis of renal failure (13).

It can also be a promising method in differentiating diffusion and perfusion problems that develop after renal transplantation (14). It is important to understand the ADC values of healthy renal parenchyma to compare ADC values obtained from DWI in kidney diseases. Therefore, studies have been conducted although the majority of them employed a 1.5 Tesla MRI device. However, the number of studies on this subject employing the 3T MRI device is limited. Hence, it is important to evaluate normal values of renal parenchyma with DWI obtained in 3T MRI devices. DWIs in our study were obtained using a 3T MRI device.

In previous studies, the ADC values of renal parenchyma were reported within a wide range between 1.64 x10^{-3} mm^2/s and 3.54 x10^{-3} mm^2/s, and these values are usually similar to the values found by us as is the case with many of the studies (8, 9, 15-25).

Some of the studies on ADC values of renal parenchyma separated ADC values as the cortex and medulla, whereas others provided a mean ADC value for the entire parenchyma like in our study. Studies that measured ADC values of the entire parenchyma were generally conducted with low b values similar to our study. On the other hand, Yildirim et al. (18, 19) and Murtz et al. (24) also used high b values such as b1000 s /mm^{2}and b1300s /mm^2 while performing DWI and found 1.90x10^{-3} mm^2/s and 1.64x10^{-3} mm^2/s, respectively.

Patients are generally asked to hold their breath while performing DWI to minimize artifacts caused by breathing. In our study, we used respiratory-triggered DWI. The images obtained did not have any artifacts.

Round-shaped ROIs and rectangular ROIs of various sizes were used while conducting ADC measurements in DWI. In our study, free-hand ROI was manually drawn on an axial b600 image, and the ADC_{mean} values seen in the ROI generated on the ADC map were recorded. Therefore, it was intended to include the contribution of the entire parenchyma within the slice to the measurement instead of making measurements in a focal area with small ROIs.

In a study by Suo et al. (26), the mean ADC value of renal parenchyma was found to be 2.23 x10^{-3} mm^2/s, which is very close to the mean ADC value found in our study. It is thought that the similarity between these values can be attributed to the fact that the b values used in DWI were similar. There was a weak negative correlation between ADC values and age in the study by Suo et al. (26). In our study, there was a strong negative correlation between ADC values and age. It was shown that glomerulosclerosis development was observed, and the renal blood flow decreased with increasing age.

There was no difference between the ADC values of the two kidneys in our study as in other studies. The fact that a difference is not normally expected between the ADC values of the two kidneys can constitute importance in pathologies involving one kidney such that the ADC values of the other kidney can be used as a reference.

It should be noted that the DWI method affects ADC values during their evaluation. In our study, a diffusion-weighted sequence was obtained at two different b values (b=0 and b=600 s/mm^2) with single-shot echo planar imaging in an axial plane. Echo planar imaging is the fastest data collection technique that is also used for dynamic and functional MR imaging. In our study, the scan duration was 2 minutes and 6 seconds.

The b value is the measure of diffusion weight. Although there have been various b values used in other studies, a low b value (600 s/mm^2) was used in our study, which enabled the reduction of motion artifacts and improvement of the signal-to-noise ratio.

This study had some limitations. First, the study was retrospective, and it comprised a small population. Second, the number of males was considerably lower than that of females, and third, measurements were performed by only one radiologist. Measurements were repeated five times, and the mean value of these measurements was used to minimize potential measurement errors.

CONCLUSION

A relationship was not observed between gender and ADC values of renal parenchyma in this study. In addition, there was no significant difference between the right and left kidney. It was found that there was a negative correlation between ADC values and age. Age may also need to be considered in interpreting ADC values in renal pathologies. Studies with larger study populations are required to confirm our findings.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Gaziantep University (decision no. 2018/246).

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Conflict of Interest: The author has no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Malayeri AA, El Khouli RH, Zaheer A, Jacobs MA, Corona-Villalobos CP, Kamel IR, et al. Principles and applications of diffusion-weighted imaging in cancer detection, staging, and treatment follow-up. Radiographics 2011; 31: 1773-91. [CrossRef]
2. Baliyan V, Das CJ, Sharma R, Gupta AK. Diffusion weighted imaging: Technique and applications. World J Radiol 2016; 8: 785-98. [CrossRef]
3. Li R, Wu G, Wang R. Application values of 3.0T magnetic resonance diffusion weighted imaging for distinguishing liver malignant tumors and benign lesions. Oncol Lett 2018; 15: 2091-6.
4. Fattahi R, Balci NC, Perman WH, Hsueh EC, Alkaade S, Havlioglu N, et al. Pancreatic diffusion-weighted imaging (DWI): comparison between mass-forming focal pancreatitis (FP), pancreatic cancer (PC), and normal pancreas. J Magn Reson Imaging 2009; 29: 350-6. [CrossRef]
5. Zhang J, Tehrani YM, Wang L, Ishill NM, Schwartz LH, Hricak H. Renal masses: characterization with diffusion-weighted MR imaging--a preliminary experience. Radiology 2008; 247: 458-64. [CrossRef]
6. Taouli B, Thakur RK, Mannelli L, Babb JS, Kim S, Hecht EM, et al. Renal lesions: characterization with diffusion-weighted imaging versus contrast-enhanced MR imaging. Radiology. 2009; 251: 398-407. [CrossRef]
7. Çolakoğlu Er H, Peker E, Erden A, Öztürk E. The utility of diffusion-weighted imaging in differentiation of papillary and clear cell subtypes of renal cell carcinoma. Acta Oncol Turc 2015; 48: 8-14. [CrossRef]
8. 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. [CrossRef]
9. Cova M, Squillaci E, Stacul F, Manenti G, Gava S, Simonetti G, et al. Diffusion-weighted MRI in the evaluation of renal lesions: preliminary results. Br J Radiol 2004; 77: 851-7. [CrossRef]
10. Razek AA, Farouk A, Mousa A, Nabil N. Role of diffusion-weighted magnetic resonance imaging in characterization of renal tumors. J Comput Assist Tomogr 2011; 35: 332-6. [CrossRef]
11. Abdel Razek AAK. Routine and Advanced Diffusion Imaging Modules of the Salivary Glands. Neuroimaging Clin N Am 2018; 28: 245-54. [CrossRef]
12. Razek A, Al-Adlany M, Alhadidy AM, Atwa MA, Abdou NEA. Diffusion tensor imaging of the renal cortex in diabetic patients: correlation with urinary and serum biomarkers. Abdom Radiol (NY). 2017; 42: 1493-500. [CrossRef]
13. Thoeny HC, Grenier N. Science to practice: Can diffusion-weighted MR imaging findings be used as biomarkers to monitor the progression of renal fibrosis? Radiology 2010; 255: 667-8. [CrossRef]
14. Thoeny HC, De Keyzer F. Diffusion-weighted MR imaging of native and transplanted kidneys. Radiology 2011; 259: 25-38. [CrossRef]
15. Damasio MB, Tagliafico A, Capaccio E, Cancelli C, Perrone N, Tomolillo C, et al. Diffusion-weighted MRI sequences (DW-MRI) of the kidney: normal findings, influence of hydration state and repeatability of results. Radiol Med 2008; 113: 214-24. [CrossRef]
16. Xu Y, Wang X, Jiang X. Relationship between the renal apparent diffusion coefficient and glomerular filtration rate: preliminary experience. J Magn Reson Imaging 2007; 26: 678-81. [CrossRef]
17. Muller MF, Prasad P, Siewert B, Nissenbaum MA, Raptopoulos V, Edelman RR. Abdominal diffusion mapping with use of a whole-body echo-planar system. Radiology 1994; 190: 475-8. [CrossRef]
18. Yildirim E, Kirbas I, Teksam M, Karadeli E, Gullu H, Ozer I. Diffusion-weighted MR imaging of kidneys in renal artery stenosis. Eur J Radiol 2008; 65: 148-53. [CrossRef]
19. Yildirim E, Gullu H, Caliskan M, Karadeli E, Kirbas I, Muderrisoglu H. The effect of hypertension on the apparent diffusion coefficient values of kidneys. Diagn Interv Radiol 2008; 14: 9-13.
20. Carbone SF, Gaggioli E, Ricci V, Mazzei F, Mazzei MA, Volterrani L. Diffusion-weighted magnetic resonance imaging in the evaluation of renal function: a preliminary study. Radiol Med 2007; 112: 1201-10. [CrossRef]
21. 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. [CrossRef]
22. Muller MF, Prasad PV, Edelman RR. Can the IVIM model be used for renal perfusion imaging? Eur J Radiol 1998; 26: 297-303. [CrossRef]

23. Kim T, Murakami T, Takahashi S, Hori M, Tsuda K, Nakamura H. Diffusion-weighted single-shot echoplanar MR imaging for liver disease. AJR Am J Roentgenol 1999; 173: 393-8. [CrossRef]
24. Murtz P, Flacke S, Traber F, van den Brink JS, Gieseke J, Schild HH. Abdomen: diffusion-weighted MR imaging with pulse-triggered single-shot sequences. Radiology 2002; 224: 258-64. [CrossRef]
25. Kilickesmez O, Yirik G, Bayramoglu S, Cimilli T, Aydin S. Non-breath-hold high b-value diffusion-weighted MRI with parallel imaging technique: apparent diffusion coefficient determination in normal abdominal organs. Diagn Interv Radiol 2008; 14: 83-7.
26. Suo ST CM, Ding YZ, Yao QY, WU GY, Xu JR. Apparent diffusion coefficient measurements of bilateral kidneys at 3 T MRI: effects of age, gender, and laterality in healthy adults. Clin Radiol 2014; 69: 491-6. [CrossRef]

How to cite:

Çolakoğlu Er H. Apparent Diffusion Coefficient Values of Renal Parenchyma in Healthy Adults: A 3 Tesla MRI Study. Eur J Ther 2019; 25(1): 64-8.