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Original Article

Effect of Iodized contrast substances used in computed tomography examination on kidney apparent diffusion coefficient (ADC) value

Bilgisayarlı tomografi incelemesinde kullanılan iyotlu kontrast maddelerin böbrek görünür difüzyon katsayısı (ADC) değerine etkisi

Seray Gizem Gür Özcan, **Sıddıka Halıcıoğlu**, **Hikmet Tekçe**

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ABSTRACT

Aim: In this prospective study, our goal is to evaluate the effect of iodine-based contrast agent on renal Apparent Diffusion Coefficient (ADC) before and after the contrast agent in patients with normal and abnormal Glomerulary Filtration Rate (GFR) values using computed tomography (CT) imaging.
Methods: The patients who applied for CT examination at an age older than 40 years and met the inclusion criteria of patient and control groups were included. DWI was evaluated by two radiologist in the same session. The range of interest (ROI) was adjusted to be less than 1.5 cm^2.The Spearman correlation test was used for statistical analysis.
Results: A total of 48 subjects (23 and 25 subjects for patient and control groups, respectively) with two DWI scans were included. ADC values were compared for both kidneys before and after the administration of the contrast agent and a significant decrease in post-ADC values was observed in the control group (right kidney pre-ADC: 2,11±0,17 $x10^{-3}$, post-ADC 2,07±0,15 $x10^{-3}$ mm^2/s, p=0,016; left kidney pre-ADC: 2,11±0,17 $x10^{-3}$ mm^2/s, post-ADC 2,04±0,14 $x10^{-3}$ mm^2/s, p=0,011). However, there was no significant difference between the patient groups according to the administration of contrast agent (right kidney pre-ADC: 1,97±0,22 $x10^{-3}$ mm^2/s, post-ADC: 1,97±0,24 $x10^{-3}$ mm^2/s, p=0,95; left kidney pre-ADC: 1,96±0,23 $x10^{-3}$ mm^2/s, post-ADC: 1,98±0,22 $x10^{-3}$ mm^2/s, p=0,64). Moreover, pre-ADC values in the patient group were relatively low. Pre-ADC values in both groups for the right kidney were 1,97±0,22 $x10^{-3}$ mm^2/s and 2,11±0,17 $x10^{-3}$ mm^2/s, respectively (p=0,016). Pre ADC values in both groups for the left kidney were 1,96±0,23 $x10^{-3}$ mm^2/s and 2,11±0,17 $x10^{-3}$ mm^2/s, respectively (p=0,018). No significant differences in the post-ADC values were observed between the two groups.
Conclusion: No decrease in ADC values was observed after the administration of iodine-based contrast agent in patients with a GFR less than 60, whereas there was a relatively high decrease in patients with normal GFR.

Keywords: Apparent diffusion coefficient, diffusion weighted MR imaging, glomerulary filtration rate

ÖZ

Amaç: Bu prospektif çalışmada Glomerüler Filtrasyon Hızı (GFR) değerleri normal ve anormal olan hastalarda kontrast madde öncesi ve sonrası iyot bazlı kontrast madde uygulamasının renal Görünür Difüzyon Katsayısı (ADC) üzerine etkisini bilgisayarlı tomografi (BT) görüntüleme ile değerlendirmeyi amaçladık.
Yöntem: 40 yaş üstü olup, bölümümüze Bilgisayarlı Tomografi (BT) çekimi için başvuran hastalardan, dışlama ve dahil edilme kriterlerine uygun bulunanlar çalışmaya dahil edildi. Difüzyon Ağırlıklı Görüntüleme (DAG) aynı seansta iki radyolog tarafından değerlendirildi. İstatistiksel analiz için spearman korelasyon testi kullanıldı.

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Corresponding Author:
S. G. Gür Özcan
ORCID: 0000-0003-3938-9802
Bursa Yüksek İhtisas Educational Research Hospital, Department of Radiology, Bursa, Türkiye
✉ seraygizemgur@yahoo.com.tr

S. Halıcıoğlu
ORCID: 0000-0001-7091-5650
Bolu Abant İzzet Baysal University, Faculty of Medicine, Department of Radiology, Bolu, Türkiye

H. Tekçe
ORCID: 0000-0002-4542-4064
Bolu Abant İzzet Baysal University, Faculty of Medicine, Department of Internal Medicine, Division of Nephrology, Bolu, Türkiye

Bulgular: Çalışmamıza iki DAG taraması olan toplam 48 kişi (hasta ve kontrol grupları için sırasıyla 23 ve 25 kişi) alındı. Sağ ve sol böbrek için kontrast madde uygulamadan önce ve uygulandıktan sonra ADC değerleri karşılaştırıldığında kontrol grubunda (sağ böbrek pre-ADC: 2,11±0,17 x10^{-3}, postADC 2,07±0,15 x10^{-3} mm^2/s, p=0,016; sol böbrek preADC: 2,11±0,17 x10^{-3} mm^2/s, postADC 2,04±0,14 x10^{-3} mm^2/s, p=0,011)ADC değerleri kontrast madde uygulandıktan sonra anlamlı düşük çıktı. Hasta grubunda kontrast madde uygulaması öncesi ve sonrası anlamlı fark saptanmadı (sağ böbrek preADC: 1,97±0,22 x10^{-3} mm^2/s, pos-tADC: 1,97±0,24 x10^{-3} mm^2/s, p=0,95; sol böbrek preADC: 1,96±0,23 x10^{-3} mm^2/s, pos-tADC: 1,98±0,22 x10^{-3} mm^2/s, p=0,64). Hasta grubunda preADC değerleri, kontrol grubuna göre anlamlı olarak düşük bulundu. Sağ böbrek için hasta ve kontrol gruplarında PreADC değerleri sırasıyla 1,97±0,22 x10^{-3} mm^2/s, 2,11±0,17 x10^{-3} mm^2/s idi (p=0,016). Hasta ve kontrol gruplarında sol böbrek için PreADC değerleri sırasıyla 1,96±0,23 x10^{-3} mm^2/s, 2,11±0,17 x10^{-3} mm^2/s idi (p=0,018). Hasta ve kontrol grupları arasında ADC sonrası değerler açısından anlamlı fark yoktu.
Sonuç: GFR'si 60'ın altında olan hastalarda iyot bazlı kontrast madde kullanımından sonra ADC değerlerinde azalma olmazken, GFR'si normal olanlarda anlamlı düşüş gözlendi.

Anahtar kelimeler: Difüzyon ağırlıklı görüntüleme, glomerüler filtrasyon hızı (GFR), görünür difüzyon katsayısı (ADC)

INTRODUCTION

Diffusion-weighted (DW) magnetic resonance (MR) imaging is an MR imaging technique that provides cellular information based on the free movement of water molecules. Diffusion imaging was first used in the diagnosis of acute stroke (1). Recently, it has also been applied to extracranial organs for diverse purposes. The kidneys are one of these organs that have been associated with DW imaging due to their role in water filtration in the body and their function in the transformation of blood into concentrated urine (1).

Previous studies carried out by Toya et al. (2) and by Xu et al. (3) examined the relationship between glomerular filtration rate (GFR) and apparent diffusion coefficient (ADC). However, no study has investigated the possible relationship between GFR and ADC before and after the administration of iodine-based contrast material.

The purpose of this study is to assess the effect of iodine-based contrast agent on renal ADC before and after the administration of the contrast agent in patients with normal and abnormal GFR values via computed tomography (CT) imaging.

METHODS

Study Population

This prospective study included a total of 75 patients who applied to the Radiology Department of our University and underwent intravenous (IV) contrast-enhanced CT for any reason between July 2015 and July 2016. The research protocol was approved by the Ethics Committee and the Scientific Research Project Commission of our University.

All participants were divided into two groups and the patient group (n=40) had no history of dialysis, malignancy, multiple myeloma, renovascular hypertension disease, or diabetic nephropathy. Patients who were over 40 years of age with GFR<60 mL/min/1.72 m^2, and whose urea-creatinine levels were measured within the past week were included in our study. The control group (n=35) had no history of dialysis, malignancy, multiple myeloma, renovascular hypertension disease, or diabetic nephropathy. Controls who were over 40 years of age with GFR> 60 mL/min/1.72 m^2, and whose urea-creatinine levels were measured within the past week were included in our study. Inclusion and exclusion criteria are shown in Table 1.

Radiological Examination

An informed consent conveying information about diffusion-weighted imaging-magnetic resonance imaging (DWI-MRI) and blood sampling, including IV intervention was obtained from each patient. Diffusion imaging was performed in each patient 24-48 hours before and 24-48 hours after the CT scan.

All participants in the study underwent DWI-MRI of both kidneys acquired by 1.5 Tesla MRI equipment (Siemens Magnetom Symphony, Erlangen, Germany). A six-channel phase-array

Table 1. Inclusion and exclusion criteria.

	Patient Group	Control Group
Inclusion criteria	>40 years of age GFR <60 mL/min/1.72 m^2 Non-dialysis patients* Urea-creatinine measured within the past week	>40 years of age GFR >60 mL/min/1.72 m^2 Urea-creatinine measured within the past week
Exclusion criteria	Any known malignancy Multiple myeloma <40 years of age Dialysis patients A known renovascular hyper-tension disease Diabetic nephropathy Patients with contraindica-tions for MRI**	Any known malignancy Multiple myeloma <40 years of age Diabetic nephropathy A known renovascular hyper-tension disease Patients with contraindica-tions for MRI**

** Non-dialysis patients group*
*** Magnetic resonance imaging*

body coil was used. An echo-planar imaging (EPI) sequence in the axial plane was obtained for DWI-MRI. The sequential parameters were as follows: (TR/TE 5500 msec/87 ms, cross-sectional thickness 6 mm, FOV 400 mm, scanning time 1 minute 46 seconds, distance factor 20%, matrix 144x192, 1240 bandwidth). Diffusion-weighted sequences were acquired in the axial plane for SSEP-SE T2 in all three directions (x, y, z) with various b values (0.800 mm^2/sec). In addition, ADC maps with isotopic images of a value of b=800 mm^2/sec were automatically generated and the measurements were made on these maps. The MRI images were analyzed using the Siemens Leonardo Software version 2.0 workstation.

Contrast Agent

In our study, 1 mL/kg of ionic iodine-based contrast agent was used. The contrast agent of 1.5 mL/kg was used only in patients undergoing CT angiography.

Biochemical Examination

Urea-creatinine values of the patients measured within the past week were reserved for CT analysis. Urea-creatinine values were re-analyzed during the DWI-MRI, which was performed 48 to 72 hours following the CT analysis.

The Modification of Diet in Renal Disease (MDRD) method was also used for calculating GFR. The MDRD is calculated by taking into account the patients' creatinine values, sex, age, and race as follows (4):

$eGFR=186.3xSCr^{-1.154}x\ years^{-0.203}$ x0.742 (if female) x1.212 (if of black race)

Creatinine was changed according to the 2012 KDIGO staging system (20):

Stage 1: increase in baseline serum creatinine values of "≥0.3" mg/dL or 1.5 to 1.9-times serum creatinine values from the baseline values.

Stage 2: 2 to 2.9-times serum creatinine from the baseline values.

Stage 3: more than 3 times serum creatinine from the baseline values or serum creatinine values of "≥4" mg/dL.

Premedication

Premedication was given by the nephrology unit to all patients with a GFR value of <60 mL/min/1.72 m^2. Premedication was administered orally + IV hydration and 600 mg N-Acetyl Cysteine (NAC) 2x1 was used for three days before the procedure.

Radiological Evaluation

All images were evaluated during the same session in consensus by two radiologists with a 10 and 4 years of experience. A total of six measurements were carried out for each patient before and after the administration of the contrast agent. Three measurements were performed for each kidney, in the upper, middle, and lower portions of the parenchymal, using the ADC maps. The measurements were made with a

Region of Interest (ROI) value of less than 1.5 cm^3 (Figure 1). The mean ROI size was fixed at 1.04 cm^3. The ROI measurements were made to avoid coinciding with any existing cystic or solid lesion. In the presence of parenchymal examination, the ROI was fixed at locations with the appropriate parenchymal thickness.

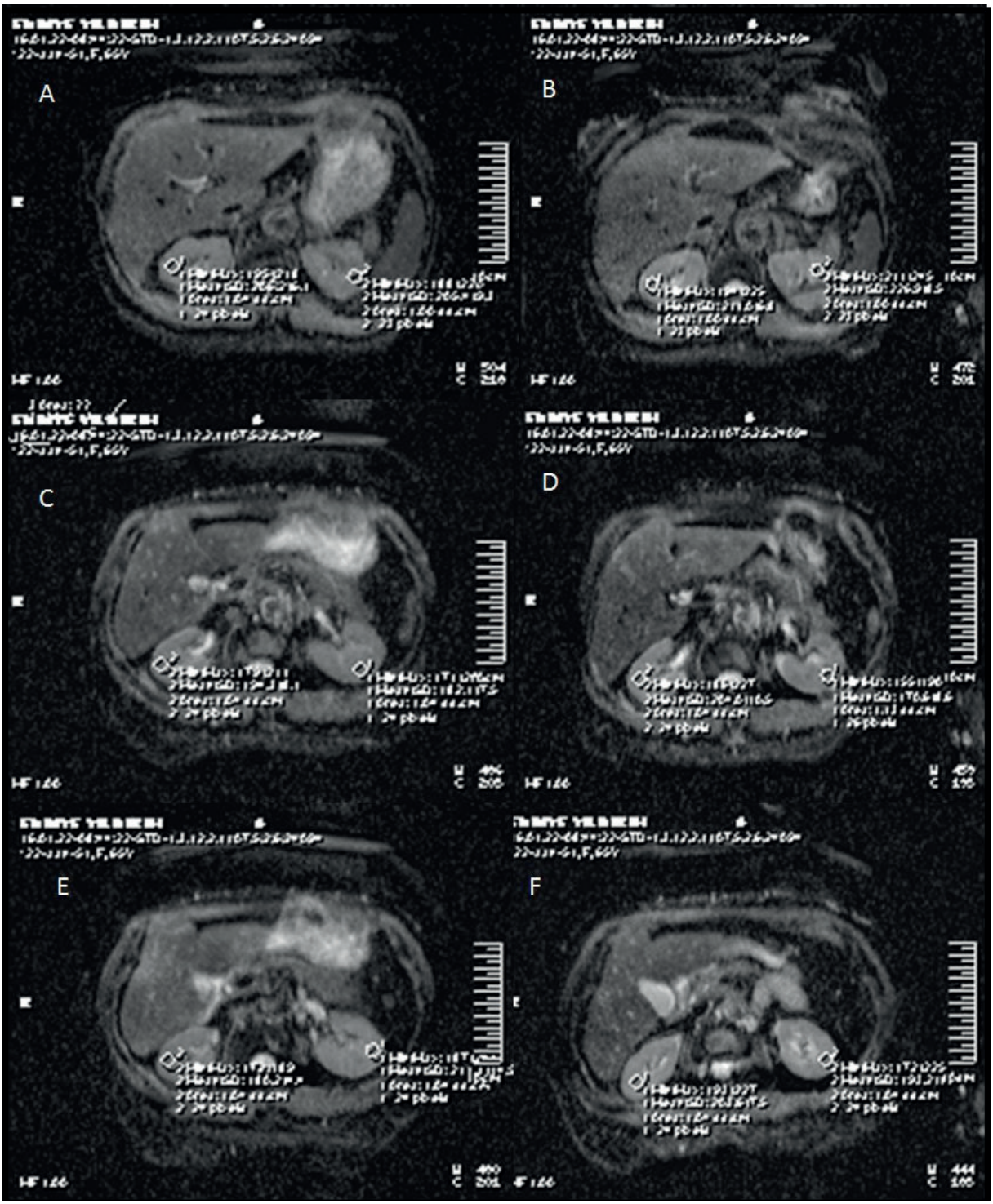

Figure 1. In a 58-year-old male patient with GFR>60, ADC measurements are observed on the upper-middle-lower pole and both kidneys on the ADC images before the MRI examination.

Statistical Analysis

Statistical analysis was performed using SPSS 20 version. Descriptive data were expressed in frequency, mean, standard deviation, and median. The one-sample Kolmogorov-Smirnov test was used to analyze the homogeneity of the distribution. Comparison between independent variables during the ADC analysis of the patient and control groups was made using the Student's t-test, while the paired samples t-test was used for intra-ADC measurement comparisons. The Pearson's correlation test was used to evaluate the correlation between the rate of GFR-creatinine change (rate of creatinine change, rate of GFR change) and the rate of ADC change. The evaluation was made as follows: "r = 0", no correlation; "0.00< r <0.25", very weak positive correlation; "0.26≤ r ≤ 0.49", weak positive correlation, "0.50 ≤ r ≤0.69", moderate positive correlation; "0.70 ≤ r ≤0.89", strong positive correlation; "0.90 ≤ r <1", very strong positive correlation; "r =1", perfectly positive correlation.

RESULTS

Quantity of patients included and excluded in the study were demonstrated for control group in Figure 2 and for Patient group in Figure 3 respectively.

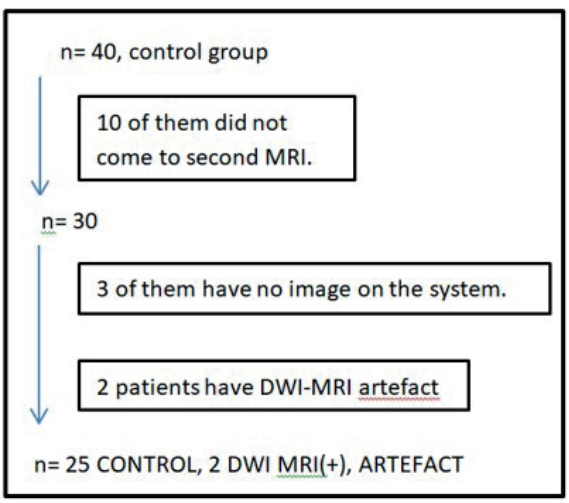

Figure 2. Control diagram.
n: quantity of patients, MRI: Magnetic resonance imaging, DWI: Diffusion weighted imaging.

A total of 23 patients were included in the patient group in the research, while 25 individuals were included in the control group. The patient group included 12 females and 11 males (age range: 42 to 84 years). The mean age was 69.78 years with a median age of 70 years. The control group included 13 females and 12 males (age range: 57 to 81 years). The mean age was 65.28 years with a median age of 63 years. No statistically significant difference was observed between the age (p= 0.069) and sex of the patients and controls (p=0.07).

Five patients and two controls underwent CT angiography with a preliminary diagnosis of embolism. Iomeprol (Iomeron, Gürel ilaç, Istanbul, Turkey) "350 mg/200", a non-ionic iodine-based contrast agent of 1.5 mL/kg was used. Iohexol (Omnipaque, Opakim, Istanbul, Turkey) "350 mg/100", a non-ionic iodine-based contrast agent of 1 mL/kg was used in 18 patients and 23 controls. The amount of contrast agent for the patient group ranged between 65 mL and 200 mL, whereas the amount in the control group ranged between 75 mL and 200 mL. No significant difference in the amount of medication was found between the patient and control groups.

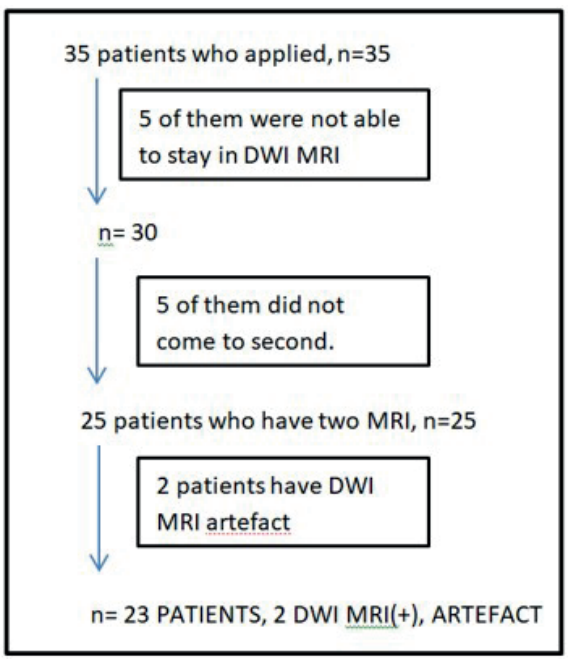

Figure 3. Patient diagram.
n: quantity of patients, MRI: Magnetic resonance imaging, DWI: Diffusion weighted imaging.

Premedication (IV-oral hydration, and N-Acetyl Cysteine, 600 mg effervescent tablet, 2x1) was given to 18 patients. Five patients who did not receive premedication due to a preliminary diagnosis of embolism underwent emergency CT angiography.

In addition, ADC measurements were made for both kidneys before and after the administration of the contrast agent in the patient and control groups in the upper, middle, and lower sections. The mean value was obtained for each kidney and compared.

The measurement of the right kidney was performed in the patient group before contrast agent administration 1.97±0.22 $x10^{-3}$ mm^2/s, and after the administration of the contrast agent 1.97±0.24 $x10^{-3}$ mm^2/s (p=0.95); whereas for the left kidney, the measurements were carried out before the administration of the contrast agent 1.96±0.23 $x10^{-3}$ mm^2/s, and after the contrast agent administration 1.98±0.22 $x10^{-3}$ mm^2/s (p=0.64). No significant difference was observed between before or after contrast agent administration for both the left and right kidneys.

In the control group, the measurements on the right kidney before the administration of the contrast agent 2.11±0.17 $x10^{-3}$ mm^2/s as well as after the contrast agent implemented 2.07±0.15 $x10^{-3}$ mm^2/s (p=0.016) were obtained; whereas the measurements for the left kidney before the administration of the contrast agent 2.11±0.17 $x10^{-3}$ mm^2/s, and after the contrast agent implemented 2.04±0.14 $x10^{-3}$ mm^2/s (p=0.011) were performed. However, there was a significant decrease in the control group after the administration of the contrast agent (Table 2).

In both the patient and control groups, there was no difference in the ADC values among the evaluation of the upper, middle, and lower sections of the kidney with respect to the administration of the contrast agent (Table 3).

On the contrary, a significant decrease was observed only in the upper section of the left kidney before and after the administration of the contrast agent in the control group. The upper section of the left kidney was measured to be 2.12±0.17 $x10^{-3}$ mm^2/s before the administration of the contrast agent, and 2.04±0.19$x10^{-3}$ mm^2/s (p=0.02) after the administration (Table 4).

Furthermore, ADC measurements of both kidneys in both groups were compared before and after the administration of the contrast agent. The ADC values for both kidneys were found to be lower before the administration of the contrast agent in the patient group. However, no difference was found between the ADC values after the administration of the contrast agent. The ADC values for the right kidney before the contrast agent were 1.97±0.22 $x10^{-3}$ mm^2/s and 2.11±0.17 $x10^{-3}$ mm^2/s (p=0.016) in the patient and control groups, respectively, while the values before the administration of the contrast agent for the left kidney were 1.96±0.23 $x10^{-3}$ mm^2/s and 2.11±0.17 $x10^{-3}$ mm^2/s (p=0.018), which were significantly lower in the patient group (Table 5).

Table 2. Mean ADC values of both kidneys in the patient and control groups be-fore and after administration of contrast agent.

			**ADC ($x10^{-3}mm^2/sec$)*	Standard deviation(±)	p
Patient***	Right[1]	Before contrast agent	1.97	0.22	0.96
		After contrast agent	1.97	0.24	
	Left[2]	Before contrast agent	1.96	0.23	0.64
		After contrast agent	1.98	0.22	
Control****	Right[1]	Before contrast agent	2.11	0.17	**0.016**
		After contrast agent	2.07	0.15	
	Left[2]	Before contrast agent	2.11	0.17	**0.011**
		After con-trast agent	2.04	0.14	

*mm^2 /seconds, ** mean Apparent Diffusion Coefficient values,*** Patients group, ****Control group,[1]Right Kidney, [2]Left Kidney, those with a p values <0.05 and significant value were bolded.*

Table 3. ADC measurements of the upper, middle, and lower sections of the right kidney in the patient and control groups.

			**ADC ($x10^{-3}mm^2/sec$)*	Standard deviation (±)	p
***Patient	Upper right[1]	Before contrast agent	2.03	0.26	0.58
		After contrast agent	1.99	0,32	
	Middle right[2]	Before contrast agent	1.96	0.22	0.88
		After contrast agent	1.96	0.22	
	Lower right[3]	Before contrast agent	1.92	0.24	0.28
		After contrast agent	1.96	0.26	
****Control	Upper right[1]	After contrast agent	2.12	0.19	0.13
		After contrast agent	2.07	0.16	
	Middle right[2]	Before contrast agent	2.12	0.18	**0.05**
		After contrast agent	2.08	0.15	
	Lower right[3]	Before contrast agent	2.09	0.22	0.15
		After contrast agent	2.06	0.20	

*mm^2 /seconds, ** mean Apparent Diffusion Coefficient values,*** Patients group, ****Control group,[1]Right Kidney Upper pole, [2]Right Kidney midlle pole, [3]Right Kidney lower pole, those with a p values <0.05 and significant value were bolded.*

Table 4. ADC measurements of the upper, middle, and lower sections of the left kidney in the patient and control groups.

			**ADC ($x10^{-3}mm^2/sec$)*	Standard deviation (±)	p
***Patient	Upper left[1]	Before contrast agent	1.98	0.27	0.90
		After contrast agent	1.98	0.25	
	Middle left[2]	Before contrast agent	1.98	0.22	0.44
		After contrast agent	2.00	0.22	
	Lower left[3]	Before contrast agent	1.92	0.28	0.55
		After contrast agent	1.94	0.24	
****Control	Upper left[1]	Before contrast agent	2.12	0.17	0.02
		After contrast agent	2.04	0.19	
	Middle left[2]	Before contrast agent	2.11	0.22	0.05
		After contrast agent	2.05	0.13	
	Lower left[3]	Before contrast agent	2.10	0.22	0.13
		After contrast agent	2.04	0.20	

*mm^2 /seconds, ** mean Apparent Diffusion Coefficient values,*** Patients group, ****Control group,[1]Left Kidney Upper pole, [2]Left Kidney midlle pole, [3]Left Kidney lower pole, those with a p values <0.05 and significant value were bolded.*

Table 5. Comparison of mean ADC values between the patient and control groups be-fore and after contrast agent administration.

			**ADC values ($x10^{-3}$ mm^2/sec)*	Standard deviation(±)	p
Right1	Before contrast agent	***Patient	1.97	0.22	**0.016**
		****Control	2.11	0.17	
	After contrast agent	***Patient	1.97	0.24	0.111
		****Control	2.07	0.15	
Left2	Before contrast agent	***Patient	1.96	0.23	**0.018**
		****Control	2.11	0.17	
	After contrast agent	***Patient	1.98	0.22	0.221
		****Control	2.04	0.14	

*mm^2 /seconds, ** mean Apparent Diffusion Coefficient values,*** Patients group, ****Control group,[1]Right Kidney, [2]Left Kidney midlle pole, [3]those with a p values <0.05 and significant value were bolded.*

ADC measurements on the upper, middle, and lower sections before and after the administration of the contrast agent were compared individually in both groups. The ADC values before the administration of the contrast agent in the patient group were found to be significantly lower in the upper section of the left kidney, the middle section of the right kidney, and the lower section of the right and left kidneys. The measurements of ADC values were as follows: upper section of the left kidney was 1.98±0.27 $x10^{-3}$ mm^2/s in the patient group and 2.12±0.17 $x10^{-3}$ mm^2/s (p=0.037) in the control group; the middle section of the right kidney was 1,96±0.22 $x10^{-3}$ mm^2/s in the patient

group and 2.12 ±0.18 x10^{-3} mm^2/s (p=0.011) in the control group; the lower section of the right kidney was 1.92±0.24 x10^{-3} mm^2/s in the patient group and 2.09±0.22 x10^{-3} mm^2/s (p= 0.014) in the control group; the lower section of the left kidney was 1.92±0.28 x10^{-3} mm^2/s in the patient group and 2.10±0.22 x10^{-3} mm^2/s in the control group.

There was a significant difference only in the middle section of the right kidney after the administration of the contrast agent. The ADC value of the middle section of the right kidney after the administration of the contrast agent was 1.96±0.22 x10^{-3} mm^2/s in the patient group and 2.08±0.15 x10^{-3} mm^2/s (p= 0.040) in the control group, which were significantly lower in the patient group.

In the comparison of ADC values of the upper, middle, and lower segments of the kidneys, no significant difference was observed between the right and left kidneys in either group. A significant difference was observed only in two individuals in the patient group when comparing the ADC values of both kidneys. The difference in ADC values was associated with unilateral atrophic kidney in one of the patients and with obstructive hydronephrosis in another.

In the comparison of GFR and creatinine values, no significant difference was observed in both groups between before and after the administration of the contrast agent. Only three patients were reported to develop contrast-induced nephropathy. No statistical comparison was made in patients who did not develop nephropathy due to the small number of patients who were reported to develop contrast-induced nephropathy.

No significant correlation was found between the ADC changes of both kidneys in terms of the percentage of GFR change and the degree of creatinine change before and after the administration of the contrast agent (p=0.712).

DISCUSSION

The measurement results obtained in our study indicate that after the implementation of the contrast agent, there was a significant decrease in the mean ADC values of the control group before and after the CT evaluation of patients administered with iodine-based contrast agent. After the administration of contrast agent, tubular necrosis occurs, leading to a decrease in renal perfusion and tubular flow. Toxic edema develops in tubular cells, resulting in tubular necrosis. This may have caused a decrease in ADC values after contrast administration in patients with healthy renal tissue.

However, no significant difference was found in the patient group. In the patient group with low GFR values, the ADC values were already low before contrast agent administration, indicating impaired tubular structure and perfusion properties of the kidney. Therefore, no significant difference was observed in the ADC values before and after contrast agent administration in the patient group.

According to our study,it is more likely to observe a decrease in ADC values in the control group, where the ADC value before contrast application was already normal, compared to the patient group. In our study, it was not possible to detect a significant change in ADC values with MRI examination in the patient group, where ADC values were already low, after contrast administration.

The comparison of the results of the two kidneys demonstrated that there was a significant difference in only two patients in the group. The difference in the ADC value of these patients was associated with unilateral atrophy of the kidney in one patient and with obstructive hydronephrosis in another patient. In the patient with obstructive hydronephrosis, the decrease in ADC value was reported to be greater in the normal kidney than in the hydronephrotic kidney. Due to the decreased

GFR and urinary stasis in the hydronephrotic kidney, the hyperosmolar contrast agent retained in the tubular system may have caused a decrease in ADC values

Contrast agents are known to cause renal vasoconstriction and tubular epithelial cell injury (5). Ischemia of renal epithelial cells is suggested to ensue as a result of these two factors (6). However, there may be no detectable change in ADC values after the administration of the contrast agent in patients with abnormal kidney function, as the ADC values decrease before the administration of the contrast agent. In the patient with obstructive hydronephrosis, the decrease in the ADC value of the normal kidney compared to the contralateral kidney can be attributed to a similar mechanism.

Furthermore, the mean ADC values of both kidneys in the patient and control groups measured before and after the administration of the contrast agent indicates that there was a significant decrease in the mean ADC value for both kidneys in the patient group before the administration of the contrast agent. ADC values for the right kidney before the administration of the contrast agent were 1.97±0.22 $x10^{-3}$ mm^2/s, and 2.11±0.17 $x10^{-3}$ mm^2/sec (p=0.016) in the patient and control groups, respectively; while values before the contrast agent for the left kidney were 1.96±0.23 $x10^{-3}$ mm^2/s and 2.11±0.17 $x10^{-3}$ mm^2/s (p=0.018). In the study conducted by Toya et al. (2), a possible decrease in the ADC value was reported to correlate with the decreased GFR values (ADC value in those with GFR value between 30-60 = 1.87±0.11 $x10^{-3}$ mm^2/s).

No significant change in the ADC value was reported in three patients who developed nephropathy after the contrast agent administration. We can attribute the absence of significant changes in ADC values despite the development of nephropaty in these three patients to the restricted number of patients included in this study. However, a significant decrease in the ADC values was found in both kidneys of two patients and only in the right kidney of one patient after the administration of the contrast agent.

Nonetheless, there are some limitations of this study. The major limitation of our study is the small sample size. This is due to the inclusion of patients above the age of 40 years in the patient group, the formation of a homogeneous group to exclude as many as possible patients with malignancy, diabetes mellitus, and diseases that may lead to nephropathy, and also due to some patients did not come for the second MRI examination.

In conclusion, no change in the ADC values was observed after the use of iodine-based contrast agent compared to pre-contrast values in patients with GFR below 60 mL/min/1.72 m^2; however, there was a significant decrease in those with a GFR higher than 60 mL/min/1.72 m^2. Based on these results, the effect of contrast agent on kidney function may not be detectable by ADC measurements in patients with decreased GFR but may help in predicting in patients with normal GFR. However, it is essential that the findings obtained in this study have to be confirmed by further large-scale studies. Hence, pre-contrast GFR and ADC values can be compared under conditions where there are sufficient number of patients who develop contrast nephropathy and those who do not. A cut-off value can also be established for the risk of developing contrast-induced nephropathy.

MAIN POINTS

In patients with a GFR value below 60 mL/min/1.72 m^2, no difference in the ADC values was observed before and after the use of iodine-based contrast agents; however, there was a significant decrease in patients with a GFR above 60 mL/min/1.72 m^2 between before and after the use of iodine-based contrast agents.

Based on these results, the effect of contrast agent on kidney function may not be detectable by ADC measurements in patients with decreased GFR but may help in predicting in patients with normal GFR.

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