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Original Research

Review of the Renal Artery Anatomy: In Chronic Kidney Disease and Healthy Individuals

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ABSTRACT

Objective: The purpose of this study was to evaluate renal arteries and aorta anatomy in patients with chronic kidney disease (CKD) and compare them with a control group.

Methods: Computed tomography images of 800 individuals (551 of that were with CKD and 249 of them were completely healthy in terms of urinary system) were evaluated retrospectively. Age range of the individuals 19 - 91 years (mean 61.15 ± 12.58). The differences between the renal arteries diameters, diameters of aorta, courses of the renal arteries, their separation levels from the aorta was investigated between the control group and patients with CKD.

Results: Diameters of aorta and renal arteries are larger in CKD patients than healthy individuals and there was a negative correlation between the diameters of aorta with glomerular filtration rate. No statistically significant difference was observed between CKD patients and healthy individuals in terms of renal artery course. No statistically significant difference was detected between CKD patients and healthy individuals in terms of the branching level of the renal arteries from the aorta.

Conclusion: Our study is one of the first studies which these measurements were made in individuals with CKD, according to the available literature. This study is important in that it reveals that the diameters of the renal arteries are statistically significantly larger in patients with CKD than in healthy individuals. These data may be important for the surgeons in interventional applications.

Keywords: Anatomy, aorta, renal artery, renal insufficiency, tomography.

INTRODUCTION

Chronic kidney disease (CKD) is a pathophysiological process with a decrease in the number of functional nephrons and urinary abnormalities [1]. Accumulation of uremic toxins, electrolyte imbalance, excessive volum load and metabolic acidosis are components of this process [2].

Death in CKD most often occurs due to cardiovascular causes, and CKD is generally accepted as an important risk factor for cardiovascular diseases [2-5]. The risk of death and cardiovascular disease are increased even in the early stages [2, 3, 6]. Both atherosclerosis and arteriosclerosis are important predisposing factors for this cardiovascular death [7]. Cardiovascular death can occur many causes for atherosclerosis to heart failure, consisting by different mechanisms [2]. Mortality rates from causes such as pulmonary embolism, cerebrovascular disease and myocardial infarction were remarkably higher in dialysis patients than in the general population [8]. All these data make it necessary to understand the changes in the vascular system of CKD patients.

With the progression of kidney failure, premature vascular aging and arterial stiffening occur. This stiffness is more prominented in the aorta than peripheric vessels. With premature vascular aging, an widening in arterial diameter develops and arterial wall hypertrophy can not compensate this [9]. Increase in arterial diameter and arterial stiffness are involved with arterial remodelling in patients with end stage renal disease [5]. Arterial remodeling, stiffness and expansion may occur even in the early stages in patients with a decrease in glomerular filtration rate (GFR) [9].

Renal arteries are two arteries branching from the aorta to the right and left sides, just below the superior mesenteric artery. The right kidney is positioned lower than the left kidney. However, the right renal artery seperated from the aorta at a higher level than the left renal artery [10].

We planned the current study to evaluate whether any changes in renal artery and aortic anatomy play a role in explaining the increased cardiovascular mortality rate and to see how the arterial wall hypertrophy and remodeling in the cardiovascular system of CKD patients reflects on the diameter of renal artery and aorta.

Main Points;

- Chronic kidney disease is a pathological process that has serious effects on the cardiovascular system.
- In this study, we aimed to investigate the effect of chronic kidney disease on renal arterial anatomy.
- Diameters of renal arteries were larger in patients with chronic kidney disease, than healthy individuals.
- Chronic kidney disease patients and healthy individuals did not exhibit a statistically significant difference in whether the renal artery followed a tortuous or straight course.
- There was no statistically significant difference between patients with chronic kidney disease and healthy individuals in terms of the vertebral level at which the renal arteries seperated from the aorta.

MATERIALS AND METHODS

In this retrospective study, approved by the local ethics committee (2019/238 approval number) we evaluated the computed tomography (CT) images of 800 individuals (551 of that were with CKD and 249 of them were completely healthy in terms of urinary system).

Right renal artery of 24 CKD patients were excluded in the study because of right renal agenesis in 4 patients, malignant neoplasm in the right kidney in 1 patient, right nephrectomy in 17 patients, and severe atrophic right kidney in 2 patients. The left renal artery of 16 CKD patients were also excluded because 1 patient had hematoma in the left kidney, left otonefrectomy in 1 patient, left nephrectomy in 11 patients and severe atrophy in the left kidney in 3 patients. The contralateral kidneys of these patients were included in the study.

Examinations were done using 256 – sections double tube CT device (Siemens, Somatom, Definition Flash, Germany) and using 16 – sections CT device (Siemens, Scope, Germany) at routine 3 mm section thickness. CT images of the patients with a cross – section thickness of 3 mm were transferred to the PACS (Picture Archiving Communication Systems). In patients with both contrast and non - contrast tomography, the examinations were performed on contrast - enhanced tomography. Renal arteries were evaluated morphologically and morphometrically on the coronal, axial and sagittal plane images.

The diameters of the renal arteries and the aorta in the level where the renal arteries depart from were measured by computed tomography (Figure 1 and Figure 2). Measurements were made by selecting the artery with the largest diameter that seperates from the aorta and enters the hilum of the kidneys in patients with more than one renal artery feeding one kidney. The difference between the renal arteries diameters, diameters of aorta, the course and shape of the renal artery, its separation level from the aorta was investigated between the healthy individuals and CKD patients. Curved and angular arteries were considered to be tortuous (Figure 3).

Statistical Analysis

IBM SPSS 21.0 package program was used to analyze the data. Before statistical analysis, the normality of the data was controlled with the Shapiro-Wilk normality test. Variables are presented as mean ± standard deviation and/or median (minmax). Independent sample t test or Mann Whitney U test were used in the comparison of the two groups. In comparison of categorical data, Pearson chi-square and Fischer's Exact test were used according to the expected frequency and size of the crosstab. Statistical significance level was taken as 5%. Relationships between numerical parameters were examined with Spearman's rho correlation coefficient.

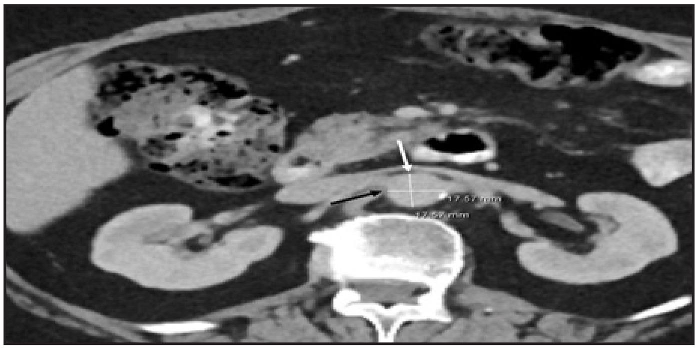

Figure 1. The morphometric measurements of the transverse (black arrow) and anteroposterior (white arrow) diameters of the aorta

Figure 2. Measurement of right renal artery diameter

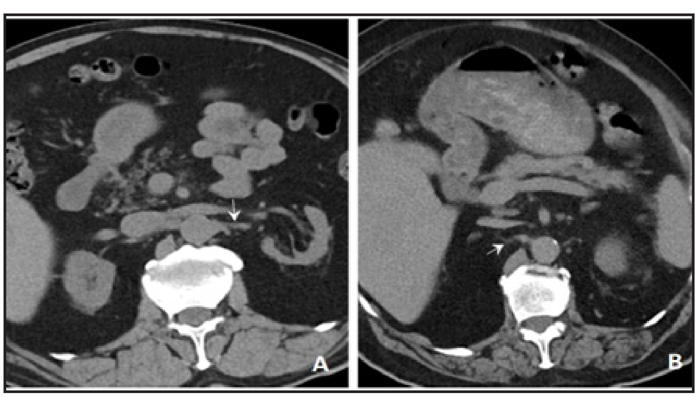

Figure 3. Course of the renal arteries **A**: a straight left renal artery, **B**: a tortuous right renal artery

RESULTS

Age range of all individuals included in study was 19 – 91 years. The average age of CKD patients is 62.01 ± 14.52, the average age of healthy individuals is 59.25 ± 6.06; and the average age of all individuals included in the study was 61.15 ± 12.58.

292 of the patients with CKD were male, 259 were female and 137 of the healthy individuals were male and 112 were female. 371 of all patients were female and 429 were male. GFR values of 439 of 551 patients with a diagnosis of CKD could be reached. The mean GFR value of patients with CKD is 44.86 ± 35.02 ml/min per 1.73 m². Only 44 of the healthy individual's GFR value (mean 101.68 ± 9.37 ml/min per 1.73 m²) were available on the records.

There was a negative correlation between the diameters of aorta with GFR in individiuals. There was a positive correlation between age and aortic diameter, there was a positive correlation between age and renal artery diameter (Table 1).

Arterial diameters of healthy individuals and CKD patients are shown in Table 2 and Table 3. All arterial diameters are larger in patients with CKD than healthy individuals. The diameter of left renal artery was statistically significantly higher ($p < 0.001$) in patients with than healthy individuals. The diameter of right renal artery was statistically significantly higher ($p < 0.001$) in patients with CKD than healthy individuals. Aortic transverse and antero-posterior diameters in the section where the right renal artery seperates from the aorta were significantly larger in CKD patients than healthy individuals ($p = 0.007$ and $p = 0.013$; respectively). The transverse diameter of the aorta, at the level where the left renal artery seperates from the aorta, was found to be statistically significantly higher ($p = 0.004$) in CKD patients compared to healthy individuals. The antero-posterior diameter of the aorta, at the level where the left renal artery seperates from the aorta, was found to be larger in CKD patients compared to healthy individuals, no statistically significant difference was observed ($p = 0.056$).

All renal arteries and aortic diameters are statistically significantly larger in males than females (Table 4 and Table 5).

Left renal artery was tortuous in 65% of CKD patients and 67.1% of healthy individuals. Right renal artery was tortuous in 70.2% of CKD patients and 74.3% of healthy individuals. There was no statistically significant difference between the healthy control group and CKD patients in terms of the course of the left and right renal artery (p = 0.579 and p = 0.239, respectively [Pearson chi-square]).

Left renal artery was most commonly separated from the aorta at the L1 corpus level in patients with CKD; in healthy individuals, it was most often separated from the L1 - L2 intervertebral disc level. Right renal artery was seperated from most frequently the L1 corpus level in patients with CKD and healthy individuals. Level of renal ostium in CKD patients and healthy individuals are shown in Table 6. No statistically significant difference was detected between healthy individuals and CKD patients in terms of the level of both the left and right renal ostium with respect to the vertebral level (p = 0.150 [Pearson chi-square], p = 0.889 [Fisher's exact test]; respectively).

Table 1. Correlation of aorta and renal artery diameters with age and GFR

	Transvers diameter of the aorta at the level of the left renal ostium	**Antero – posterior diameter of the aorta at the level of the left renal ostium**	**Diameter of the left renal artery**	**Transvers diameter of the aorta at the level of the right renal ostium**	**Antero – posterior diameter of the aorta at the level of the right renal ostium**	**Diameter of the right renal artery**
Age						
r	0.404	0.396	0.170	0.389	0.393	0.136
p	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**
N	*784*	*784*	*784*	*776*	*776*	*776*
GFR						
r	-0.264	-0.263	-0.008	-0.230	-0.224	-0.084
p	0.000**	0.000**	0.854	0.000**	0.000**	0.071
N	*475*	*475*	*475*	*466*	*466*	*466*

**p < 0.001, r = Correlation coefficient, N= Number of cases, GFR= Glomerular filtration rate
Spearman's rho correlation test

Table 2. Measurements of aorta and renal artery diameters according to the groups

	All individuals N = 784	**Healty individuals N = 249**	**Patients with CKD N = 535**	**p**
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	
Antero-posterior diameter of the aorta at the level of the left renal ostium	18.81 ± 2.95 mm	18.54 ± 2.55 mm	18.94 ± 3.11 mm	0.056
Diameter of left renal artery	5.58 ± 1.55 mm	5.13 ± 1.15 mm	5.79 ± 1.66 mm	0.000**
	All individuals N = 776	**Healty individuals N = 249**	**Patients with CKD N = 527**	**p**
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	
Transvers diameter of the aorta at the level of the right renal ostium	19.26 ± 3.03 mm	18.87 ± 2.54 mm	19.45 ± 3.23 mm	0.007*
Antero-posterior diameter of the aorta at the level of the right renal ostium	19.25 ± 2.93 mm	18.90 ± 2.47 mm	19.42 ± 3.11 mm	0.013*
Diameter of right renal artery	5.49 ± 1.61 mm	5.05 ± 1.15 mm	5.70 ± 1.74 mm	0.000**

*p < 0.05, **p<0.001, N= Number of cases, SD= Standart Deviation, CKD= Chronic kidney disease
Independent sample t test

Table 3. Transvers diameter of the aorta at the level of the left renal ostium according the groups

	All individuals N = 784	Healty individuals N = 249	Patients with CKD N = 535	p
Median	18.19 mm	17.4 mm	18.45 mm	0.004*
Minimum	10 mm	12 mm	10 mm	
Maximum	40 mm	26 mm	40 mm	
*p < 0.05, N= Number of cases, CKD= Chronic kidney disease Mann Whitney U test				

Table 4. Diameters of aorta and renal arteries according to the sex.

	All individuals N = 784	Female N = 365	Male N = 419	p
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	
Antero-posterior diameter of the aorta at the level of the left renal ostium	18.81 ± 2.95 mm	17.67 ± 2.69 mm	19.80 ± 2.80 mm	0.000**
Diameter of left renal artery	5.58 ± 1.55 mm	5.36 ± 1.46 mm	5.78 ± 1.60 mm	0.000**
	All individuals N = 776	**Female N = 360**	**Male N = 416**	**p**
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	
Transvers diameter of the aorta at the level of the right renal ostium	19.26 ± 3.03 mm	18.20 ± 2.84 mm	20.18 ± 2.90 mm	0.000**
Antero-posterior diameter of the aorta at the level of the right renal ostium	19.25 ± 2.93 mm	18.21 ± 2.69 mm	20.15 ± 2.83 mm	0.000**
Diameter of right renal artery	5.49 ± 1.61 mm	5.20 ± 1.58 mm	5.75 ± 1.59 mm	0.000**
**p<0.001, N= Number of cases, SD= Standart Deviation, CKD= Chronic kidney disease Independent sample t test				

Table 5. Transvers diameter of the aorta at the level of the left renal ostium according sex

	All individuals N = 784	Female N = 365	Male N = 419	p
Median	18.19 mm	17 mm	19.09 mm	0.000**
Minimum	10 mm	10 mm	13 mm	
Maximum	40 mm	28 mm	40 mm	
**p<0.001, N= Number of cases Mann Whitney U test				

Table 6. Renal ostium levels respect to the vertebraes.

Right renal ostium level	**All individuals** **N = 776**	**Healthy individuals** **N = 249**	**Patients with CKD** **N = 527**
T12	16 (2.1%)	5 (2%)	11 (2.1%)
T12 – L1	58 (7.5%)	19 (7.6%)	39 (7.4%)
L1	330 (42.5%)	100 (40.2%)	230 (43.6%)
L1 – L2	282 (36.3%)	97 (39%)	185 (35.1%)
L2	78 (10.1%)	26 (10.4%)	52 (9.9%)
L2 – L3	11 (1.4%)	2 (0.8%)	9 (1.7%)
L3 – L4	1 (0.1%)	0 (0%)	1 (0.2%)
Left renal ostium level	**All individuals** *N = 784*	**Healthy individuals** *N = 249*	**Patients with CKD** *N = 535*
T12	11 (1.4%)	3 (1.2%)	8 (1.5%)
T12 – L1	44 (5.6%)	17 (6.8%)	27 (5%)
L1	301 (38.4%)	82 (32.9%)	219 (40.9%)
L1 – L2	303 (38.6%)	111 (44.6%)	192 (35.9%)
L2	115 (14.7%)	34 (13.7%)	81 (15.1%)
L2 – L3	10 (1.3%)	2 (0.8%)	8 (1.5%)
N: Number of cases, CKD= Chronic kidney disease			

DISCUSSION

Recognition of the normal anatomy of the renal arteries is of great importance for surgeons and radiologists performing diagnostic or therapeutic renal angioplasty. Given the impact of CKD on the cardiovascular system, it is inevitable that the artery that supplies the kidney will receive its share of this effect. Our study is one of the first studies to evaluate the renal artery anatomy in terms of arterial diameter, arterial course and renal ostium level in CKD patients, according to the available literature.

We found that all renal arteries and aorta diameters were larger in individuals with CKD than in healthy individuals. Exposure of the arterial wall to high pressure triggers an increase in vessel diameter [11]. Kidney patients, with difficult blood pressure control, are expected to have larger arterial diameters than healthy individuals. The fact that the individuals included in our study are generally composed of the elderly population and hypertension is seen quite frequently in the advanced age suggests that impaired blood pressure control is not the only responsible for the larger artery diameters in patients with CKD. Briet et al.[4] in their study, they found that the internal diameter of the common carotid artery was significantly larger in CKD patients than in hypertensive and normotensive individuals. They reported that the lumen diameter, which increases as the GFR decreases, coincides with the arterial accelerated aging in CKD patients [4]. Our results are consistent with previously reported information in the literature that arterial diameter increase and arterial enlargement are observed in CKD patients [4, 9].

Although all aortic and renal artery diameters were found to be larger in individuals with CKD compared to healthy individuals, it was interesting that GFR correlated with aortic diameter but not with renal artery diameter (Table 1). This can be explained by the close association of arterial enlargement in patients with CKD, with arterial remodeling and arterial stiffening. Because accelerated aging, which affects the cardiovascular system of CKD patients, is more evident in the aorta than peripheric vessels [9].

Mazzacaro et al. [12] in their study, examined computed tomography angiograms of individuals with thoracoabdominal aneurysm, non-dilation of thoracoabdominal aorta and infrarenal aneurysm; they found that the mean diameter of the right renal artery in all individuals was 5.4 mm and the mean diameter of the left renal artery was 5.2 mm. Hazırolan et al. [13] reported that the diameter of the renal artery was 5 - 6 mm. As reported by Merklin and Michels [14] the right and left renal artery diameters were generally similar and the mean value was 5.5 mm. The values of 5.49 mm for the right renal arteries and 5.58 mm for the left renal arteries, which we found by taking the mean value of the diameters of the right and left renal arteries of all individuals, were compatible with the literature.

Arterial tortuosity has been associated with hypertension and some vascular diseases in various articles [11, 15, 16]. In addition, knowing whether the renal arteries are tortuous is important in the management of complications after renal transplantation [17]. Hegedüs [18] found that 61.2% of the arteries were tortuous and 38.8% were straight. In our study, we found a similar curl rate for both groups, slightly higher than Hegedüs reported. Because arterial curvature has previously been associated with causes that disrupt organ blood supply, such as transient ischemic attacks and myocardial ischemia [11, 16], it was interesting that we found a higher rate of renal artery tortuosity in healthy individuals (67.1%) than in patients with CKD (65%), although there was no statistically significant difference. This situation can be clarified by the fact that increased blood pressure, which is one of the important factors affecting artery tortuosity, could not be evaluated and patients data were not included in the study, considering the increased incidence of cardiovascular hypertension in the elderly population.

There have been many studies investigating the localization of the renal ostium respect to the vertebral level [19-22]. Çiçekcibaşı et al. [21] found that in a study conducted on 90 fetuses, the right renal artery was separated at the 92.2% L1 corpus level and the 3.8% at the L2 corpus level; these rates were 94.1% and 3.8%, respectively, for the left renal artery. Özkan et al. [20] in their study by evaluating the angiographies of 855 patients, showed that the right renal artery was separated from 43% L1, 23% L1 - L2 and 32% L2; reported that these rates were 37%, 22% and 38% for the left renal artery, respectively. Fataftah et al. [22] found that the right renal artery is separated at the level of L1 41%, L1 - L2 36.6%, L2 17.2%; they reported that these rates were 40.5%, 34.4% and 22% for the left renal artery, respectively. We detected that the right renal artery was separated from the aorta in 42.5% of the individuals at the L1 corpus level, in 36.3% at the L1 - L2 intervertebral disc level and in 10.1% at the L2 corpus level; these rates were 38.4%, 38.6.1% and 14.7% for the left renal artery, respectively. These rates we found were compatible with other radiological studies in the literature.

A study conducted in patients with suspected cardiovascular hypertension showed that the right renal artery was separated at the level of 31% L1, 17% L1 - L2, 49% L2 and reported that these rates were 22%, 22%, 50% for the left renal artery, respectively [19]. We found it appropriate to compare the data of this study with the results of patients with CKD in our study. We showed that the right renal artery was separated from the level of 43.6% L1 corpus level, 35.1% L1 - L2, and 9.9% L2 in patients with CKD, and these rates were 40.9%, 35.9% and 15.1% for the left renal artery, respectively. Differences in the data presented by two studies with similar patient populations, and in the current study, there was no statistically significant difference between the CKD patients and healthy individuals in terms of the level at which renal arteries leave the aorta may indicate that there is no relationship between kidney disease and level of the renal ostium with respect to the vertebral level.

Limitations

Our study had some limitations as in all retrospective studies. Since our study was a retrospective study, the blood pressure values of our study group patients diagnosed with CKD by the nephrology clinic and control group patients could not be listed. Because the effects of blood pressure control on the cardiovascular system cannot be ignored, it is important to standardize patients according to their blood pressure values. In addition, since the study group included chronic kidney disease patients, computed tomography of a small number of patients could be obtained with contrast. Since it is very difficult to evaluate the arterial structures in non-contrast tomography, we were able to include fewer individuals with clear images than we planned.

CONCLUSIONS

In conclusion this study shows that, diameters of aorta and renal arteries are larger in CKD patients than healthy individuals. There was a negative correlation between the diameters of aorta with GFR. There was a positive correlation between age and aortic diameter. There was a positive correlation between age and renal artery diameter. There was no statistically significant difference in renal artery course between patients with CKD and healthy individuals. There was no statistically significant difference between patients with CKD and healthy individuals in terms of the level at which the renal arteries branched from the aorta.

Acknowledgments: Part of this study was presented as an oral presentation at 2nd International Medical Congress of Izmir Democracy University (IMCIDU 2020)

Conflict of interest: The authors declare that they have no conflicts of interest.

Informed Consent: Not available.

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Ethical Approval: All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study approved by the local ethics committee (2019/238 approval number).

Author Contributions: Conception: NÜD - Design: NÜD, GÇ - Supervision: NÜD - Fundings: none -Materials: GÇ, MK, İA - Data Collection and/or Processing: GDA, GÇ, MK, İA - Analysis and/or Interpretation: GDA, NÜD, GÇ, MK, İA - Literature: GDA, NÜD, ZF - Review: ZF, AKK - Writing: GDA, ZF, AKK - Critical Review: ZF, AKK

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