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Computed Tomographic Assessment of Renal Volume and Its Associative Factors Among Adults

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ABSTRACT

Background: Knowledge of normal renal volume is a vital parameter for clinical assessment of renal diseases because renal size is altered by various medical conditions. Variations in renal dimension in different populations and it's relation to individual's body parameters are evident. Different studies have recommended the need for measurement of renal dimension for specific population. This study assesses normal range of renal volume in the study population and measures their correlation with individual's body parameters.

Methods: This descriptive study was done in 261 adults. After renal length measurement on reformatted coronal images, renal width and renal thickness on axil images, renal volume was calculated by ellipsoidal formula. Descriptive statistics and parametric tests were used to evaluate the association between renal volume and different parameters.

Results: This study showed a significant difference in mean renal volume between male (right and left mean renal volume 120.52 $\pm$ 26.84 cm^3 and 121.00 $\pm$ 27.23 cm^3 respectively) and female (right and left mean renal volume 110.11 $\pm$ 21.79 cm^3 and 111.15 $\pm$ 22.34 cm^3 respectively) on each side. Similarly, a significant positive correlation was found between renal volume and body height, body weight and BMI of participant for both kidneys however a significant negative correlation was observed between renal volume and age 40 years and above for both kidneys.

Conclusions: This study provides morphometric data regarding normal kidneys and concludes that male renal volume is more than female and renal volume is correlated to individual's body parameters.

Keywords: Morphometric; nomogram; renal volume

INTRODUCTION

Many renal diseases adversely affect the renal size and impair it's function.[1] In practice, renal size estimation includes renal length, renal volume and cortical thickness measured by different modalities but renal length measurements are easy however the most accurate is the renal volume.[2-6] Many studies by different researchers worldwide have concluded that renal size varies with body habitus, sexes and ethnicities and correlate with age, height, weight and body mass index (BMI).[7, 8] Several studies have highlighted the need of assessment of renal dimensions for each population and same nomogram can not be used for all populations because different populations have different ethnicities even though from the same country.[1, 8-11] The knowledge of renal size in normal population serves as reference for both diagnostic and prognostic purposes.[5] In this context, this study provides reference standards of renal volume in local population.

METHODS

This descriptive cross-sectional study was performed in the department of radiodiagnosis and Imaging, Bir hospital, National Academy of Medical Science (NAMS) from 15 May, 2019 to 15 November, 2019 after approval from the Institutional Review Board (IRB), NAMS. A purposive sample of 261 adult patients (above 18 years) coming for contrast enhanced computed tomography (CECT) abdomen with no previous history of renal disease, hypertension and diabetes and serum creatinine less than 1.4 mg/dl was included in the study. After informed written consent, required clinical history, observation

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of USG report, patient's weight and height were taken by using digital weighing machine and stadiometer. All computed tomography (CT) scans were performed using 128 slice CT, Philips. Scanning was performed in helical mode with routine protocol with standard acquisition parameters (64 x 0.625 mm collimation, 230 effective mAs, 120kVp, pitch=0.891, 0.75 second rotation time, 512 X 512 Matrix). Patients CT scan images interpreted as normal bilateral kidney and not degraded by motion were selected for measurement. Bilateral renal parameters i.e. renal length (from superior pole of kidney to the inferior pole of the kidney on coronal reformatted image), renal width (the maximum distance between outer renal margin and renal sinus on the axial image) and renal thickness (the maximum distance between the anterio-posterior wall of the kidney) were measured in NCCT (Figure 1). The renal width and renal thickness were measured on the same axial image but not necessarily same image for the both side (left and right kidney). The linear lines measuring renal width and renal thickness were set perpendicular to each other. During measurement, images were viewed in soft tissue window (WW-350 and WL-60) for optimum visualization of renal margins. BMI and renal volume were calculated by using the formula, BMI = (weight in Kg)/(height in m^2) and renal volume = renal length x renal width x renal thickness x 0.523 respectively.

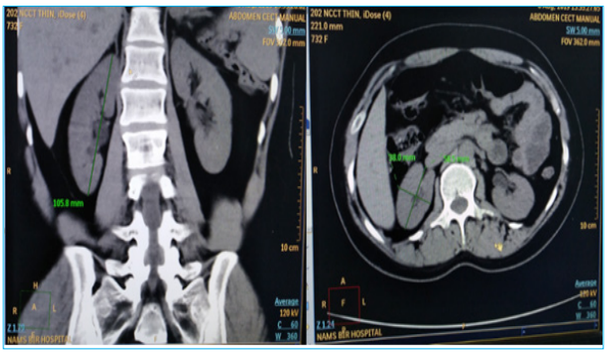

Figure 1. Measurement of right renal length on coronal reformatted CT image (left) and right renal width and thickness on axial CT image (right).

Data obtained was analyzed through Statistical Package for Social Science (SPSS) program, version 16. Mean value and standard deviation (SD) were used for descriptive statistics and categorical variables were presented as percentage. The level of significance was kept at $p < 0.05$. Comparative analysis between left and right renal volume of male and female were done by means of independent t-test. Differences between left and right mean renal volume among various groups of age, height, weight and BMI were compared using one way analysis of variance (ANOVA) test. Similarly, Karl Pearson's co-efficient correlation test was used to assess the degree of association of renal volume with age, height, weight and BMI.

RESULTS

Of the total 261 participants in the study, there were 139 male and 122 female. Majority of the participants (48.6%) were from age group 19 to 38 years and only 7.3% of the subjects were of above 68 years. The mean age and standard deviation (SD) were 41.48 years and 15.74 years respectively. BMI of the participants ranged from 15.62 to 37.95 Kg/m^2 (mean ± SD = 23.22 ± 3.97 Kg/m^2). Majority of the participant's (45.2%) BMI were normal (18.5 to 22.99 Kg/m^2) while 9.0% were underweight (BMI < 18.5 Kg/m^2), 17.2% overweight (BMI 23 to 24.99 Kg/m^2) and 28% were obese (BMI ≥ 25 Kg/m^2).

In males, the right and left renal volume ranged from 64.63 cm^3 to 193.63 cm^3 (mean ± SD = 120.52 ± 26.84 cm^3) and 79.30 cm^3 to 216.90 cm^3 (mean ± SD = 121.00 ± 27.23 cm^3) respectively while volume of the right kidney varied between 64.59 cm^3 to 170.03 cm^3 (mean ± SD = 110.11 ± 21.79 cm^3) and that of left ranged from 61.19 cm^3 to 175.71 cm^3 (mean e ± SD = 111.15 ± 22.34 cm^3) in females. In total, volume of right kidney ranged from 64.59 to 193.63 cm^3 (mean ± SD = 115.65 ± 25.11 cm^3) and that for left kidney varied from 61.19 cm^3 to 216.90 cm^3 (mean ± SD = 116.40 ± 25.50 cm^3). In majority of participants, right and left renal volume were 100 to 120 cm^3 followed by 120 to 140 cm^3 in both male and female (table 1).

Table 1. Distribution of renal volume in male and female.

Renal volume (cm^3)	Male		Female	
	Right Kidney (f)	Left Kidney (f)	Right Kidney (f)	Left Kidney (f)
< 80	8	3	8	8
80-100	23	27	34	30
100-120	43	46	45	46
120-140	35	36	20	25
≥ 140	30	27	15	13
Total	139	139	122	122

f - Frequency

A significant difference in mean renal volume (10.41 ± 5.05 cm^3 for right and 9.85 ± 04.89 cm3 for left kidney) was found between male and female for both kidney (t-score 3.41 and 3.21 for right and left kidney respectively and p-value < 0.05) but the difference in mean renal volume between left and right kidney was insignificant (t-value -0.335 and p-value 0.737).

Renal volume was compared with different age, height, body weight and BMI group of the participants. Significant differences in mean renal volume were observed for both right and left kidney in different age group (F-ratio 8.03 and 3.74 for right and left kidney respectively and p-value < 0.05 for both kidney), in different height group (F-ratio 10.12 and 6.68 for right left kidney respectively and p-value <0.05 for both kidney), in different weight group (F-ratio 19.35 and 12.21 for right and left kidney respectively and p-value <0.05 for both kidney) and in different BMI group (F-ratio 7.57 and 7.33 for right and left kidney respectively and p-value <0.05 for both kidneys) (Table 2 and Table 3).

Table 2. Renal volume distribution according to age.

Age (Year)	Frequency	Renal volume ± SD (cm^3)	
		Right	Left
19 - 28	69	117.66 ± 21.32	116.97 ± 22.27
29 - 38	58	124.18 ± 23.55	123.39 ± 23.67
39 - 48	48	121.63 ± 24.81	118.63 ± 25.94
49 - 58	37	113.23 ± 30.95	115.59 ± 32.52
59 - 68	30	103.55 ± 18.79	111.81 ± 25.54
≥ 69	19	91.05 ± 17.44	96.13 ± 13.35
F-ratio		8.03	3.74
p-value		0.000	0.003

Table 3. Renal volume distribution according to height, weight and BMI.

Independent variables		Frequency	Renal volume ± SD (cm^3)	
			Right	Left
Height (Centimeter)	< 150	31	99.04 ± 23.29	98.79 ± 20.19
	150 - 160	115	112.36 ± 22.13	116.43 ± 23.81
	160 - 170	91	122.27 ± 25.47	120.69 ± 26.01
	≥ 170	24	127.81 ± 26.48	122.70 ± 28.81
	F-ratio		10.12	6.68
	p-value		0.00	0.00
Weight (Kilogram)	< 50	54	98.94 ± 15.04	103.84 ± 17.46
	50 - 60	95	115.44 ± 25.01	114.80 ± 23.94
	60 - 70	74	118.00 ± 24.06	118.47 ± 24.42
	≥ 70	38	135.34 ± 23.63	134.19 ± 30.48
	F-ratio		19.35	12.21
	p-value		0.00	0.00
BMI (Kilogram/m^2)	< 18.5	25	98.94 ± 15.04	99.91 ± 17.12
	18.5 - 23	118	115.44 ± 25.01	113.19 ± 22.53
	23 - 25	45	118.00 ± 24.06	123.89 ± 26.48
	≥ 25	73	135.34 ± 23.63	122.60 ± 28.49
	F-ratio		7.57	7.33
	p-value		0.00	0.00

Applying post hoc (LSD) analysis for right kidney, the maximum mean renal volume difference was 30.58 cm^3 in pair age group 39-48 years and ≥ 69 years, 28.76 cm^3 in pair height group <150 and ≥ 170 cm, 36.39 cm^3 in pair weight group <50 and ≥ 70 Kg and was 25.65 cm^3 in pair BMI group <18.5 Kg/m^2 and 23-25 Kg/m^2 while the minimum difference was 10.94 cm^3 in pair age group 29-38 years and 49-58 years, 9.90 cm^3 in pair height group 150-160 and 160-170 cm, 16.49 cm^3 in pair weight group <50 and 50-60 Kg and was 7.43 cm^3 in pair BMI group 18.5-23 Kg/m^2 and ≥ 25 Kg/m^2. For left kidney, the maximum mean renal volume difference was 27.26 cm^3 in pair age group 29-38 and ≥ 69 years, 23.91 cm^3 in pair height group <150 and ≥ 170 cm, 30.35 cm^3 in pair weight group <50 and ≥ 70 Kg and was 23.97 cm^3 in pair BMI group < 18.5 Kg/m^2 and 23-25 Kg/m^2 while that of minimum difference was 11.58 cm^3 in pair age group 29-38 and 59-68 years, 17.63 cm^3 in pair height group <150 and 150-160 cm, 10.96 cm^3 in pair weight group <50 and 50-60 Kg and was 9.40 cm^3 in pair BMI group 18.5-23 Kg/m^2 and ≥ 25 Kg/m^2.

The study showed increasing renal volume from age 18 to 39 years and then decreasing from age 40 year and above (Figure 2).

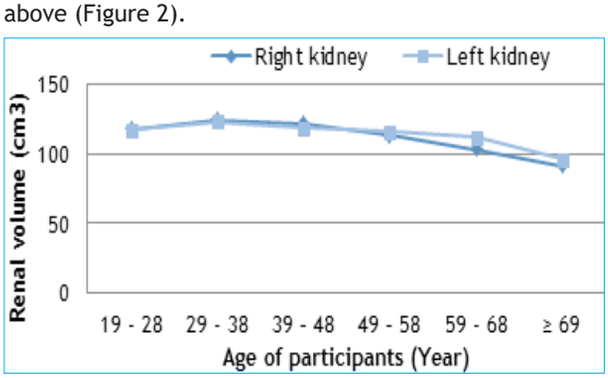

Figure 2. Relation between renal volume and age.

A significant negative correlation was found between renal volume with increasing age from 40 years and above for both kidneys (r-value -0.358 for right kidney and -0.200 for left kidney and p-value <0.05 for both

kidney) while there was insignificant correlation between renal volume and age up to 39 years for both kidneys (r-value 0.074 for right kidney and 0.065 for left kidney and p-value > 0.05). Similarly, a significant positive correlation was also found between renal volume and height (r-value 0.323 and 0.246 for right and left kidney respectively and p-value < 0.05 for both kidney); renal volume and weight (r-value 0.344 and 0.380 for right and left kidney respectively and p-value < 0.05 for both right and left kidney) and renal volume and BMI (r-value 0.274 and 0.253 for right and left kidney respectively and p-value < 0.05 for both right and left kidney) among the participants (Figure 3).

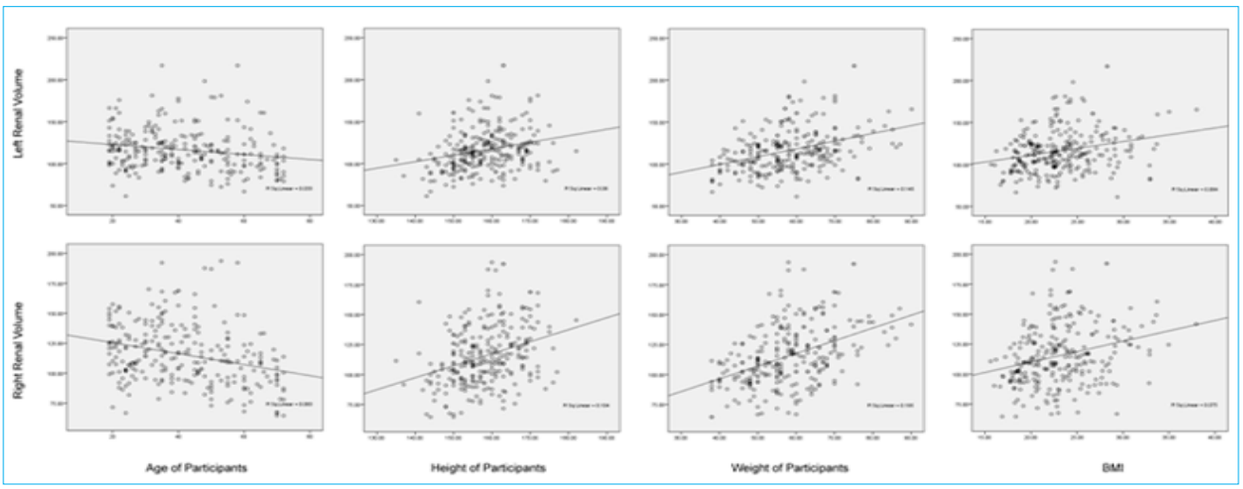

Figure 3. Correlation of renal volume with age, height, weight and BMI of the participants.

DISCUSSION

The left renal volume was more than the right but the difference was not significant (t-value 0.335 and p-value 0.737). However, a significant difference in mean renal volume between male and female was found for both right and left kidneys (t-value 3.41 and p-value 0.001 for right kidney and t-value 3.21 and p-value 0.001 for the left kidney). These findings are similar with the studies performed by Prasad VA and Kumar US [12], Paul L et al.[1], Okur A et al.[13], Maaji SM et al.[14], Ugboma EW et al.[15] and Talhar SS et al.[16]

Significant differences were found in mean renal volume among different age groups for both right and left kidney showing insignificant increase in renal volume with age till 39 years (r-value 0.074 for right kidney and 0.065 for left kidney and p-value >0.05 for both kidneys) while significant negative correlation was found between renal volume and age 40 years and above for both kidneys (r-value -0.358 for right kidney and -0.200 for left kidney and p-value < 0.05 for both kidney). Similar results were reported in studies of Prasad VA and Kumar US[12], Maaji SM et al.[14], Buchholz NP et al.[9] and Okur A et al.[13] A similar CT based study done by Talhar SS et al.[16] found significant negative correlation between left renal volume and age (p = 0.009) in male while in females, right renal volume showed significant negative correlation with age (p=0.039) and concluded statistically significant differences in left kidney volume among the subjects below 60 years and 60 years and above.

Statistically, significant differences were found in mean renal volume among different height groups for both right and left kidney and a significant positive correlation was found between renal volume and height of participant for both left and right kidneys (r-value 0.323 and 0.246 for right and left kidney respectively and p-value < 0.05 for both kidney). This result is in the line with the study carried by Okur A et al.[13] and Talhar SS et al.[16]

A significant difference in mean renal volume was observed for both right and left kidney in different weight groups (F-ratio 19.35 for right and 12.21 for left kidney and p-value 0.00 for both kidney). A significant positive correlation was also found between renal volume and weight of participants for both kidneys (r-value 0.3442 for right and 0.380 for left kidney and p-value less than 0.05 for both right and left kidney). This result of the current study is in the line with the study carried by Talhar SS et al.[16] and Okur A et al.[13]

Significant differences were found in mean renal volume among different BMI groups for both right and left kidneys and a significant positive correlation was also found between renal volume and BMI of participant for both kidneys as r-value were 0.274 and 0.253 for right

and left kidney respectively and p-value less than 0.05 for both right and left kidney. This result of the present study is in line with the result of the study conducted by Buchholz NP et al.[9] who observed renal volume correlated well with BMI although this correlation was not found for the right kidney in the 31 to 40 BMI group. A similar study conducted by Okur A et al.[13] showed a significant correlation between renal volume and BMI ($p<0.05$, $r = 0.20$) which supports the result of the current study.

CONCLUSIONS

The present study provides a normograms of renal volume in the study population and shows left renal volume slightly higher than that of right but is statistically not significant. However, mean renal volume of males were found to be significantly higher than that of females for both right and left kidneys. This study also concludes that renal volume is correlated to age, sex, side (left and right) height, weight and BMI of the individual.

CONFLICTS OF INTERESTS

None

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