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Original Article

Radiology Section

Renal Volume Nomogram on Computed Tomography in North Indian Population Correlated with Age, Gender and Height

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ABSTRACT

Introduction: Assessment of renal size is a difficult task in view of the complex shape of kidney. Among different imaging modalities Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) owing to their 3 Dimensional reconstructional ability are quite helpful in assessment of kidney size. A relationship between renal size and anthropometric parameters is an issue of interest.

Aim: To assess kidney size in North Indian adult population using CT and to assess its relationship with age, sex and height.

Materials and Methods: This was a cross-sectional study done over a period of two years (January 2018 to December 2019) in which a total of 300 adults aged between 20-90 years with normal renal function were enrolled. Age and sex of subjects was noted and their heights were measured. All the subjects underwent computed tomographic assessment for kidney size using 384 Slice Somatom Force, Seimens Corp. Multidetected CT machine. Contrast enhanced abdominal CT was performed to visualise the kidneys. Linear renal dimensions (length, lateral diameter, anteriorposterior diameter) were measured and renal volume was calculated using the ellipsoid volume formula. Data was analysed using Statistical Package for the Social Sciences (SPSS) version 21.0 software. Independent samples t-test, paired t-test, Analysis of Variance (ANOVA) and Pearson coefficient constants were calculated.

Results: A total of 300 subjects were included, with the mean age of subjects were 41.12 years. Exactly half (50%) were males. Mean kidney size was 94.62 (95% CI: 90.27-98.97) cm^3 for right side and 119.84 (95% CI=113.40-126.29) cm^3 for left side. Average kidney size was 107.23 (95% CI=102.66-111.80) cm^3. For both the sides, males had significantly larger kidney as compared to that of females (p-value <0.01). With increasing age, a significant decline in kidney size was observed (p-value <0.001). With increasing height, a significant increase in kidney size was observed (p-value <0.001). Height showed a significant positive correlation with both right and left side of kidney size (r=0.588, p-value <0.05).

Conclusion: The present study provided the normal range for kidney size among North Indian adults using CT. The findings showed an age, gender and height dependence of kidney size in present study population.

Keywords: Adults, Anthropometry, Kidney size

INTRODUCTION

Assessment of normal kidney size is important to determine its morphological variation from diseased state. A significant correlation between kidney size and renal function has also been documented [1,2]. However, measurement of kidney size is considered to be difficult as kidney has a complex shape. In the earlier days when X-ray was the only imaging modality, the kidney size was considered only in terms of length and breadth. But with the emergence of advanced imaging modalities like Ultrasound (USG), CT and Magnetic Resonance Imaging (MRI) that can help in measuring the third dimension, i.e., depth can help in making the volumetric assessments of kidney which might help in clinical decision-making. Although, volumetric assessments of kidney can be made through USG yet they are often criticised for significant inter and intra-observer variability [3].

Among more advanced imaging techniques CT is considered to be quite useful in making in-vivo measurements of kidney [4]. As far as measurement of kidney size using MRI is considered, it requires complex disc summation method to achieve high accuracy as the ellipsoid formula used for the purpose ends up in high discrepancy in kidney size [5]. In the recent years, CT has emerged as a useful modality for accurate in-vivo measurement of kidney size even with the help of formula for calculation of volume of ellipsoid [6]. A relationship between kidney size and anthropometry has also been documented [7,8]. Gender differences and age related changes in kidney size have also been reported [9]. The present study was conducted to analyze the kidney size of north Indian adult population using Computed Tomography (CT) and to explore the relationship of kidney size with age, sex and height.

MATERIALS AND METHODS

This cross-sectional study was carried out in the Department of Radiodiagnosis, Era's Lucknow Medical College and Hospital, Lucknow over a period of two years starting from January 2018 to December 2019 after obtaining approval from Institutional Ethics Committee and after getting informed consent from the participants.

Inclusion criteria: Patients coming for abdominal CT without any urinary/renal complaint and normal renal function (Serum ceratinine <1.5 mg/dL); Systolic Blood Pressure (SBP)/Diastolic Blood Pressure (DBP) <140/90 mmHg were included in the study.

Exclusion criteria: Pregnant women and those with any acute or chronic illness, allergy to contrast medium were excluded. Patients with history of hypertension, diabetes or any other condition that could result in any renal pathology were also excluded from the study.

Sample size calculation: The sample size assessments were based on the study by Shin HS et al., [8]. The sample size was calculated at 95% confidence level with a projection of 95% of renal volumes within 100-200 cm^3 range (i.e., mean value 150 and a Standard Deviation of 25 cm^3) and at a margin of error of 5%. The sample size was calculated using the formula:

$$\frac{Z^2 \times SD^2}{d^2}$$

Where z is a constant with value 1.96 at 95% confidence, SD is standard deviation=25 and d is margin of error or 5. The calculated sample size was 96. As authors also planned to carry out layered analysis for three different age groups and males and females separately, hence, we targeted sufficiently higher number of adults in order to make out layered comparisons. Hence, a sample size of 300 was targeted. A total of 300 adults age group between 20-90 years with 150 males and 150 females were enrolled in the study. At enrolment, the age and gender details were noted and height of all the participants was noted by stadiometer.

All the participants were then subjected to computed tomographic assessment using 384 Slice Somatom Force, Seimens Corp. Multidetected CT machine. The participants were advised to drink 1.0 to 1.5 liters of drinking water almost one hour prior to CT evaluation. Images were obtained prior to and after the administration of 150 mL of iodinated contrast media during the parenchymal phases of enhancement. The enhanced CT acquisition extended from the diaphragm to the pubic symphysis with breath hold on inspiration.

After obtaining all the images, the measurements were done by two trained Radiologists. The pole-to-pole distance was measured on the coronal plane of CT image and was noted as renal length while diameter from the renal hilum to the opposite side on the transverse plane was measured and noted as renal width. Renal depth was measured in terms of anteroposterior diameter and was measured as the longest distance on an axis perpendicular to the renal width on the transverse plane. Renal volume was calculated in cubic centimeters, using the equation for an ellipsoid:

Volume (cm^3)=length×lateral diameter×anteroposterior diameter×$\pi/6$ [10]

Measurements made by both the radiologists were tallied. A difference of more than 1 mm in one dimension and a difference of >5 mm^3 in volume was subjected to re-evaluation. In case this difference could not be resolved then the average of measurement of two observers for all the three dimensions was taken as the representative value.

Renal volume/size was calculated separately for both right and left sides. Average renal volume was calculated by summing the volume of two sides and then dividing it by two.

STATISTICAL ANALYSIS

Data was analysed using Statistical Package for the Social Sciences (SPSS) version 21.0. Data has been represented as numbers and percentages, mean±SD and 95% confidence intervals. Independent samples t-test and ANOVA were used to compare the mean data. Bivariate correlation was assessed using Pearson correlation coefficient. A p-value less than 0.05 were considered as statistically significant.

RESULTS

Mean age of study population was 41.12±12.57 years. Mean kidney size for right side was 94.62±38.29 (95% CI=90.27-98.97) cm^3 whereas for left side it was 119.84±56.74 (95% CI=113.40-126.29) cm^3. Mean average kidney size was 107.23±40.24 (95% CI=102.66-111.80) cm^3. Mean kidney size of left side was significantly larger as compared to that of right side (p<0.001). Height of study population ranged from 120 to 187 cm with a mean of 153.93±13.68 cm^3 [Table/Fig-1].

The size of left kidney was significantly higher in males as compared to that of females for both right and left sides. Mean average kidney size of males was 117.36±44.99 cm^3 as compared to 97.10±31.91 cm^3 as observed in females. On comparing the kidney size of males with that of females, it was found to be significantly larger for both the sides as well as for average kidney size too (p<0.001). Correlation value for gender was not calculated as gender is not a continuous variable but a categorical variable.

Variables	Values
Age, Mean±SD (range) (years)	41.12±12.57, (20-90)
Gender (n,%)	
Male	150 (50%)
Female	150 (50%)
Renal size (cm^3), Mean±SD (95% CI)	
Right side	94.62±38.29 (90.27-98.97)
Left side	119.84±56.74 (113.40-126.29)*
Average	107.23±40.24 (102.66-111.80)
Height (cm), Mean±SD (range)	153.93±13.68 (120-187)

[Table/Fig-1]: General profile of Study Population (n=300).
*p<0.001 as compared to right side (Paired t-test), p-value <0.05 considered significant

On age-wise evaluation, left kidney was found to be larger as compared to that of right side for all the three age groups. Mean average kidney size of those aged 20-39 years, 40-59 years and >60 years was 113.67±43.61, 106.57±35.56 and 83.80±29.02 cm^3 respectively. With increasing age a significant decrease in size of both right and left kidneys as well as that of average kidney size was observed (p<0.001). In patients with height <145 cm, 146-160 cm and >160 cm average kidney size was 74.55±18.67, 94.99±22.32 and 146.22±36.55 cm^3 respectively. With increasing height a significant increase in size of right and left kidneys as well as for average kidney size (p<0.001) [Table/Fig-2].

Characteristics	n	Renal size (cm^3)		
		Right side Mean±SD (95% CI)	Left side Mean±SD (95% CI)	Average Mean±SD (95% CI)
Sex				
Male	150	105.26±44.22 (98.12-112.39)	129.47±61.37* (119.57-139.37)	117.36±44.99 (110.10-124.62)
Female	150	83.98±27.55 (79.54-88.43)	110.22±50.07* (102.14-118.30)	97.10±31.91 (91.95-102.25)
Statistical significance		t=5.001; p<0.001	t=2.977; p=0.003	t=4.499; p<0.001
Age (years)				
20-39	153	99.60±42.75 (92.78-106.42)	127.74±62.4* (117.76-137.72)	113.67±43.61 (106.71-120.64)
40-59	108	92.58±32.69 (86.35-98.82)	120.56±50.67* (110.89-130.22)	106.57±35.56 (99.79-113.35)
>60	39	80.70±30.14 (70.93-90.47)	86.89±33.46 (76.05-97.74)	83.80±29.02 (73.81-92.91)
Statistical significance		F=4.110; p=0.017	F=8.047; p<0.001	F=9.050; p<0.001
Height (cm)				
<145	81	69.95±18.50 (65.85-74.04)	79.15±25.37 (73.54-84.76)	74.55±18.67 (70.16-78.52)
146-160	115	85.67±25.28 (81.00-90.34)	104.31±36.54* (97.56-111.06)	94.99±22.32 (90.87-99.11)
>160	104	123.73±43.11 (115.35-132.12)	168.72±58.17* (157.40-180.03)	146.22±36.55 (139.11-153.33)
Statistical significance		F=74.66; p<0.001	F=110.3; p<0.001	F=174.94; p<0.001

[Table/Fig-2]: Comparison of renal size with respect to gender, age and height (overall study population).
*p<0.001 as compared to right side (Paired t-test), p-value <0.05 considered significant

A significant negative correlation of kidney size (volume) (right, left) with age whereas height showed a significant positive correlation with kidney size [Table/Fig-3].

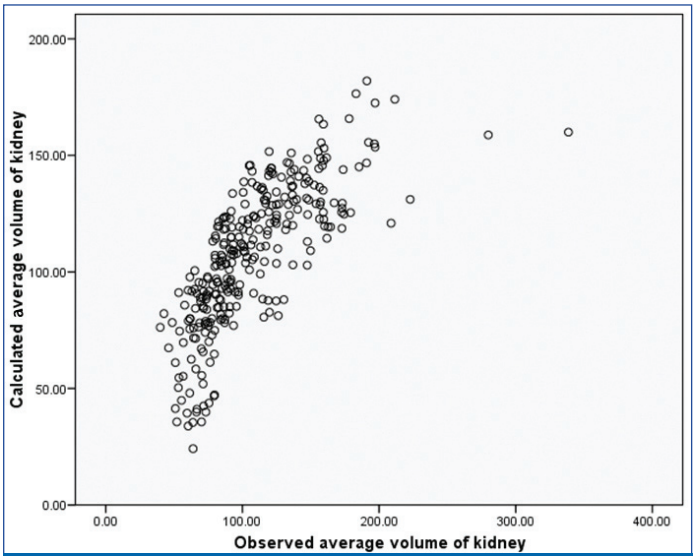
Variable	Correlation with right renal volume (r)	Correlation with left renal volume (r)	Correlation with average renal volume (r)
Age	-0.150*	-0.213*	-0.223
Height	0.588*	0.664*	0.748*

[Table/Fig-3]: Correlation of renal volume with age and height (Pearson correlation coefficient).
*p<0.001, p-value <0.05 considered significant

On multivariate assessment, where average kidney size was taken as a dependent variable on independent variables sex, age and height, only height was found to be significantly associated with kidney size (p<0.001). The calculated average kidney volume using this multivariate model showed a strong positive correlation with observed average kidney volume (r^2=0.753) [Table/Fig-4,5].

Model		Unstandardised coefficients		Standardised coefficients	t sig	p-value
		B	Std. error	Beta		
1	(Constant)	-237.466	23.779		-9.986	<0.001
	Age	-.200	0.126	-0.063	-1.596	0.111
	Sex (M=1, F=2)	5.358	3.387	0.067	1.582	0.115
	Height	2.241	0.127	0.762	17.678	<0.001

[Table/Fig-4]: Multivariate Regression to assess a relationship between average renal volume with independent variables sex, age and height.
r^2=0.753; Derived equation: Average renal volume=-237.466-0.200*Age+5.358* Sex+2.241* Height



[Table/Fig-5]: Correlation between observed and calculated kidney size (r^2=0.753).

DISCUSSION

The present study provides normative data for kidney sizes of a North Indian adult population using CT. In present study, it was found that the size of right and left kidney of the north Indian population to be 94.62±38.29 (95% CI=90.27-98.97) cm^3 and 119.84±56.74 (95% CI=113.40-126.29) cm^3 respectively thus showing the left kidney to be significantly larger than the right kidney. Compared to present study, Talhar SS et al., in his study reported the mean kidney size of right and left sides to be 94.18±23.68 and 98.07±24.92 cm^3 respectively in an adult Indian population [10]. Park CW et al., in a study among Korean children reported CT measured renal volume to be 92.99±37.94 cm^3 for right and 102.89±42.70 cm^3 for left side [7]. All these studies had reported mean kidney volume in 90 to 120 cm^3 range as also observed in present study.

However, Shin HS et al., in their study among young Korean adults (21-40 years) reported mean CT measured kidney volume to be 207.32±37.50 and 203.26±38.60 cm^3 respectively for right and left sides [8], thus showing the kidney volume to be much larger than the present study as well as other studies [7,10]. The reason for this difference could be owing to difference in method of measurement. In present study, the kidney volume was calculated using ellipsoid formula as was also done by Park CW et al., and Talhar SS et al., [7,10], however, Shin HS et al., used disc summation method for this purpose [8]. Disc summation method has been reported to end up in smaller kidney sizes as compared to ellipsoid formula in other studies too [5,11]. Mode and method of measurement, hold an important key to estimation of kidney size. The kidney size measured by imaging modalities might also show considerable variability from actual measurements. It would be pertinent to mention here that in a postmortem study using ellipsoid formula for measurement of kidney volume. Johora F et al., reported the mean kidney volume of patients in 54.46±4.02 to 74.47±6.22 cm^3 for right side and from 53.15±1.98 to 75.90±6.80 cm^3 for left sides, thus showing that actual postmortem measurements were much lower than the estimated kidney size using imaging modalities [12]. In order to remove this discrepancy, it is recommended that imaging studies followed by actual measurements should be carried out in a suitable population with normal kidneys, such as kidney donors in order to find the level of reliability of imaging modalities as compared to actual measurements. Till then the limitation of imaging modalities should be kept in mind and imaging measurements using different modalities should be considered in view of the imaging modality used and method of calculation of volume. As far as larger size of left kidney as compared to that right kidney, not only the other studies in general report such a difference in volume [5,7,8,10-12] but other studies using linear measurements in terms of renal length or width also show a similar difference using different modalities and methods of calculation under different clinical conditions [13-15].

In present study, it was found that the mean kidney size of males is larger as compared to females for both left as well as right side as well as for average kidney size. Contrary to findings of present study, Lavanya BC and Sukumar S, reported both the length as well as width of left as well as right kidney to be larger in females as compared to that in males [16]. Okur A et al., too showed that ultrasonographically measured kidney volume of both right and left side was larger in males as compared to females [17]. The larger kidney volume of males as compared to females could probably be linked to anthropometric and body habitus differences. In present study, a significant association of increasing height with increasing kidney size was found. A significant correlation between height and kidney size has also been reported by Kim JH et al., in children, Okur A et al., in adults as well as Srivastava A et al., and Kang KY et al., in healthy adult kidney donors [13,17-19]. In present study, in multivariate analysis, sex did not emerge as a significant independent predictor of kidney size thus highlighting the fact that the kidney size relationship with sex was confounded by body habitus, i.e., height.

In present study, it was found that with increasing age, there was a declining or increasing trend of kidney size. However, while correlation of height with age was moderate to strong (r=0.588 and 0.664 for right and left kidney and r=0.748 for average kidney volume), it was of much lower order with age (r=-0.150 and -0.213 for right and left kidneys and r=-0.223 for average kidney volume). In their study, Srivastava A et al., also observed declining trends of kidney length with increasing age, however, they did not report it to be significant statistically [13]. Okur A et al., too in their study found an inverse correlation of age with kidney volume but did not find it to be significant statistically [17].

A relationship between increasing age and declining kidney size might be attributed to the declining Body Surface Area (BSA) with increasing age in both males as well as females. A significant relationship between BSA and kidney size has been reported by previous workers [9,16,17]. Other factors like body weight might also affect the same [9,15]. As far as inverse relationship of age with kidney size is concerned, Dunnill MS and Haley W in their study on 68 pair of kidneys among individuals aged ranging from birth to 90 years reported the combined volume of the both kidneys at birth about 20 ml and in healthy adults about 250 ml and in old age the volume declines [20]. Thus, established an inverse relationship between kidney volume and age. Talhar SS et al., in a recent study also found a similar relationship while measuring renal volume using CT [10]. As such the relationship between age and renal volume could be a complex one and might be confounded by other factors. In present study, it was found that relationship between age

and kidney size is a confounded one and does not hold true in multivariate assessment.

In present study, normative data for computed tomographically measured kidney size in a healthy adult population of North India are presented and also highlighted the impact of anthropometric parameters, sex and age on the renal size in both univariate as well as multivariate assessment. There was a huge need for such database as these measurements will help in both diagnosis as well as treatment planning of patients for various kidney ailments. Further studies to corroborate the findings of present study with inclusion of more variables in order to minimise the confounding effect of different variables and to provide a larger pool of normative data is recommended.

Limitation(s)

The present study was first attempted to provide a normative data for computed tomographically measured kidney size in a north Indian population. Its applicability in various environments needs to be corroborated.

CONCLUSION(S)

The present study provided a normative data for computed tomographically measured kidney sizes in a north Indian population and showed gender, age and height related differences influencing the kidney size. Further studies with inclusion of more variables will help to assess the relationship in a broader perspective.

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