Original Article

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Computed Tomographic Estimation of Relationship between Renal Volume and Body Weight of an Individual

Anatomy Section

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ABSTRACT

Introduction: Knowledge of normal range of size and volume of abdominal organs plays a vital role in clinical practices as various medical conditions affects the abdominal organs causing alteration in their dimensions.

Aim: The present retrospective study was done to establish the normal range of renal volume in study population and to see the correlation between renal volume and body weight of an individual.

Materials and Methods: Computed tomographic evaluations of kidneys were performed on 140 kidneys of 70 individuals who had undergone abdominal CT scan for indications other than renal disease. We also excluded the patients diagnosed to have renal cysts, hydronephrosis or other renal diseases on CT examination. Renal length, width and depth were measured. Renal volume of both the kidneys was calculated by formula Kidney Volume (KV) =л/6 x Renal length (L) x Renal width (W) x Renal depth (D). Various body parameters like age, weight, sex were also recorded in the data sheet.

Results: Mean renal volume for the right kidney was 83.26±18.33 cm^3 for females (33 females out of 70) and 103.92±23.27 cm^3 for males (37 males out of 70). However, mean renal volume for the left kidney was 89.17±19.41 cm^3 in females and 106±26.79 cm^3 in males. Left renal volume was apparently more than right renal volume, though statistically insignificant. In males, mean kidney volume was found to be 104.96 cm^3 whereas in females, it was found to be 86.21 cm^3. Kidney volume was found to be significantly greater in males than females among study population (t=3.79, p=0.0001). Renal volume significantly correlated with age and body weight of an individual.

Conclusion: This study is a sincere attempt to establish a normograms of renal volume in study population. For the clinical assessment of renal pathologies, knowledge of renal volume is a vital parameter. In study group, most significant parameter associated with renal volume is body weight which can be used as an adjunct while evaluating renal pathological conditions. Of all the radiological imaging techniques, abdominal coronal computed tomography scan provides most accurate renal measurements.

Keywords: Body weight, Kidney volume, Normograms

INTRODUCTION

There exists a potential significance in knowing the volume and size of abdominal organs. Since multitude of medical conditions are closely linked with the alteration in organ dimensions leading to changes in their volume and size [1]. Systemic diseases like hypertension, diabetes mellitus, micro and macro vascular diseases, various congenital anomalies, urinary tract diseases leads to changes in renal dimensions and thus acts as an important sign of renal diseases [2,3]. Thus, essential prerequisite to diagnose any renal disease is first to have knowledge about normal ranges of renal dimensions which can be used to calculate renal volume. Kidney volume being more sensitive index of renal size for diagnosing renal pathology, we used this parameter in our study. Moreover, renal volume is considered to be an excellent parameter in predicting the renal function which is found to be correlated very well with body indexes [4-6]. In the renal transplant patient's prognosis of the graft kidney depends upon pretransplant renal volume [7]. Pourmand G et al., reported that when the donor graft mass is inferior to recipient's Body Mass Index (BMI), rate of acute allograft rejection phenomenon is raised [8].

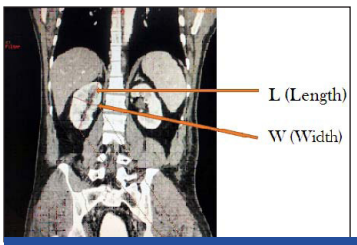
Most recent imaging methods used to measure normal renal volume is ultrasonography, computed tomography and Magnetic Resonance Imaging (MRI) [9-12]. On comparing these three recent imaging techniques, sonographic measurements of organs is demonstrated to be underestimated when they are compared with measurements taken by CT and MRI [11,13]. Thus, we assessed the renal dimensions using CT images due to its ready availability as compared to MRI.

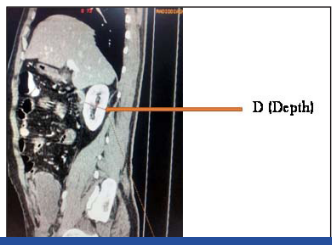
Renal dimensions give an idea about the health status of kidney. Changing renal dimensions between successive examinations form a vital parameter while evaluating and taking the follow up of patients with renal pathology [14]. Thus, present study aimed to determine the renal volume calculated using renal dimensions (using CT) and to explore its association with the body weight of an individual.

MATERIALS AND METHODS

This was the prospective observational study carried out in the Department of Anatomy and Outpatient Department of Radiodiagnosis, Mahatma Gandhi Institute of Medical Sciences, Sevagram, Wardha, Maharashtra, India. We have taken approval from Institutional Ethical Committee and also obtained informed consent from the study group for study protocol. We studied 70 consecutive patients above the age of 18 years who had undergone abdominal CT scan from March 2015 to November 2016 for indications other than renal pathology. The study group included outpatients and in patients undergoing abdominal CT examinations due to common clinical complaints such as abdominal pain, loss of weight, constipation, vomiting not suggestive of renal involvement. We also have seen the patient's medical record and subjects with underlying disease such as hypertension; diabetes mellitus were excluded from the study. Moreover, subjects diagnosed to have renal disease on CT examination were also excluded from the study.

Computed tomographic evaluation: All the seventy subjects were evaluated with a contrast enhanced abdominal CT scan. Linear dimensions of kidney such as renal length (L), renal width (W) and





[Table/Fig-1]: Abdominal CT scan-coronal section. **[Table/Fig-2]:** Abdominal CT scan-sagittal section.

renal depth (D) were measured. Renal length (L) was the maximum longitudinal length of the kidney determined on the coronal slice parallel to the long axis of kidney [Table/Fig-1].

Renal Width (W) was determined as maximum width perpendicular to the renal length on the identical slice of CT where renal length was localized [Table/Fig-1]. Renal Depth (D) was calculated as maximum depth of kidney right angled to the renal length in a thick sagittal slice of CT scan image [Table/Fig-2]. Kidney Volume (V) was calculated using the formula as Kidney volume (V) =л/6 x L x W x D [15]. Apart from recording renal dimensions, subject's age, sex and weight were also recorded.

STATISTICAL ANALYSIS

Results were calculated as mean ± SD. t-test was used to analyse the relation between left and right kidneys. Pearson's correlation coefficient was used to evaluate the relationship between different parameters. When p-value was below 0.05, the obtained results were considered to be significant. Coefficient of determination (R2) was used to establish any significant relationship if any between the different parameters and were used to derive equations. Scatter graphs were also prepared showing significant relationship between parameters. Statistical analysis was done using SPSS 17.0 version and Graphpad Prism 6.0 version.

RESULTS

One hundred and forty kidneys of 70 individuals were included in the present study. There were 37 males (52.9%) and 33 females (47.1%). Their age ranged from 21 years to 79 years with mean age of 46.94±17.98 years in males and 47.09±15.49 years in females. Weight of study group ranged from 30 kg to 77 kg with mean weight of 51.48±9.77 kg in males and 46.72±9.27 kg in females. Mean weight of study group was 49.24±9.77 kg. Mean body weight of males was greater than that of females in study group (t=4.33, p=0.041) [Table/Fig-3].

Mean renal volume for the right kidney was 83.26±18.33 cm^3 for females and 103.92±23.27 cm^3 for males. However, mean renal volume for the left kidney was 89.17±19.41 cm^3 in females and 106±26.79 cm^3 in males. We also calculated the mean renal volume for right kidney and left kidney as 94.18±23.68 cm^3 and 98.07±24.92 cm^3 respectively in combined study group consisting of both males as well as females. We observed that left kidney volume was apparently larger than right kidney volume, though statistically insignificant (t=0.94, p=0.34) [Table/Fig-4].

In males, mean kidney volume was found to be 104.96 cm^3 whereas in females it was found to be 86.21 cm^3. Kidney volume was found to be significantly greater in males than females among study population (t=3.79, p=0.0001) [Table/Fig-5]. Left renal volume

Variables	Male	Female	Combined	t-value	p-value
No of subjects	37(52.9%)	33(47.1%)	70		
Mean Age(yrs)	46.94±17.98	47.09±15.49	47.01±16.73	0.36	0.971,NS
Mean Weight(kg)	51.48±9.77	46.72±9.27	49.24±9.77	4.33	0.041,S

[Table/Fig-3]: Somatic variables of the study population.
Student's unpaired t-test used.

	Male		Female		Combined	
	Rt Kidney	Lt Kidney	Rt. Kidney	Lt. Kidney	Rt. Kidney	Lt Kidney
Renal volume	103.92± 23.27	106± 26.79	83.26± 18.33	89.17± 19.41	94.1823.68	98.0724.92
t-value,p-value	0.35,p=0.72,NS		1.27,p=0.28,NS		0.94,p=0.34,NS	

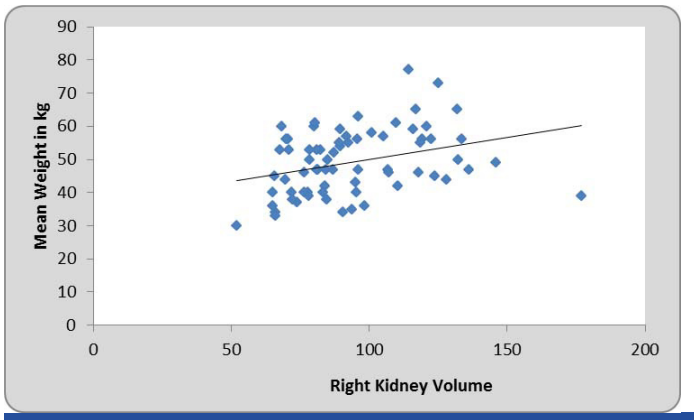
[Table/Fig-4]: Distribution of renal volume in males, females and combined group.
Student's unpaired t-test used

Gender	N	Mean renal volume	Std. Deviation	Std. Error Mean	t-value	p-value
Male	37	104.96	23.23	3.81	3.79	0.0001,S
Female	33	86.21	17.20	2.99		

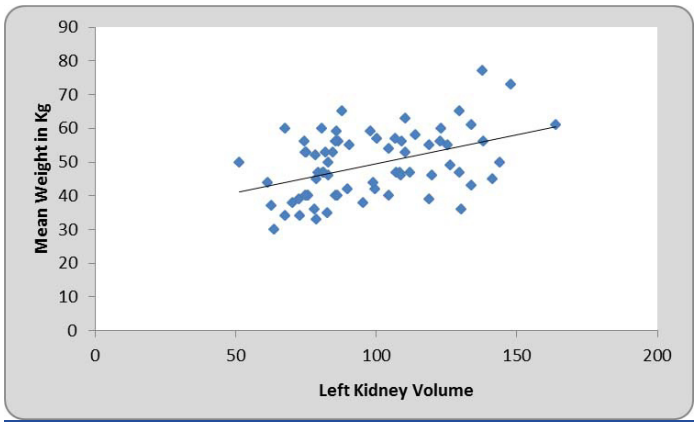
[Table/Fig-5]: Relationship between kidney volume and body parameters.
Student's unpaired t-test used

	Male		Female		Combined	
	Kidney Volume		Kidney Volume		Kidney Volume	
	Right	Left	Right	Left	Right	Left
Age	-0.129	-0.421	-0.355	-0.198	-0.181	-0.321
p-value	0.52,NS	0.009,S	0.039,S	0.27,NS	0.133,NS	0.007,S
Weight	0.193	0.372	0.336	0.416	0.323	0.434
p-value	0.25,NS	0.024,S	0.057,NS	0.016,S	0.006,S	0.0001,S

[Table/Fig-6]: Relationship between kidney volume and body parameters.



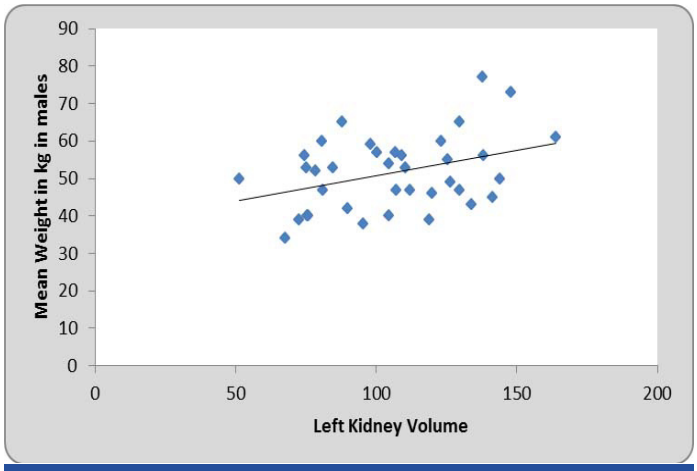
[Table/Fig-7]: Distribution of mean body weight versus right kidney volume.



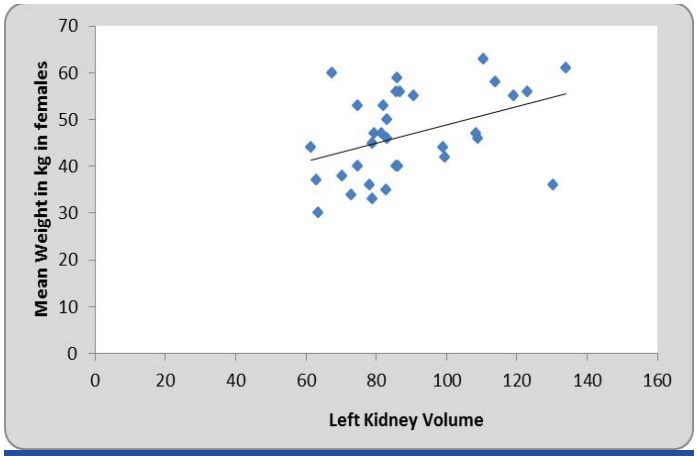
[Table/Fig-8]: Distribution of mean body weight versus left kidney volume.

showed significant inverse relationship with the age of an individual (p=0.007) where right kidney volume showed apparently inverse relationship with the age of an individual which was statistically insignificant (p=0.133). In males, left kidney volume presented statistically negative correlation with age of an individual (p=0.009) whereas in females, right renal volume showed significant negative correlation with individual's age (p=0.039) [Table/Fig-6].

We observed significantly positive linear relationship between individual's body weight and renal volume (For right renal volume,



[Table/Fig-9]: Distribution of mean body weight in males versus left kidney volume.



[Table/Fig-10]: Distribution of mean body weight in females versus left kidney volume.

p=0.006 and for left renal volume, p=0.0001) in combined group consisting of males and females [Table/Fig-6-8].

Left kidney volume presented statistically positive linear correlation with the weight of an individual in males (p=0.024) as well as in females (p=0.016) [Table/Fig-6,9,10]. Mean right kidney volume in subjects aged less than 60 years was found to be 94.94±22.07 cm^3 and in subjects aged more than 60 years was found to be 92.27±27.86 cm3 (t=0.42, p=0.67) whereas mean left kidney volume in subjects aged less than 60 years was 101.96±24.25 cm^3 and more than 60 years was 88.33±24.47 cm^3 (t=2.11, p=0.038). Thus, we noted the statistically significant differences in left kidney volume among the subjects less than 60 years and more than 60 years.

Furthermore, linear regression equations for predicting variable (Renal volume) from independent variable (Weight) were derived as follows:

Right renal volume= 55.56+0.78×weight (R2 =0.10)

Left renal volume = 43.51+1.10×weight (R2 =0.18)

DISCUSSION

Estimation of renal volume has determined to be a most sensitive parameter in detecting renal pathology as compared to any other single linear measurements of kidney and found to be correlated better with renal mass. Furthermore renal volume has been shown to correlate very well with number of functioning nephron thus reflecting over the renal functions [10,16]. Thus, the most sensitive index of kidney size for detecting renal abnormalities is renal volume. However, because of the complex renal shape there occurs a difficulty in assessing the renal volume [17,18].

In our study we calculated the renal volume using the formula л/6x L x W x D. Mean renal volume for right kidney and left kidney was 94.18±23.68 cm^3 and 98.07±24.92 cm^3 respectively in combined study group consisting of both males as well as females. Different studies carried out in past using different imaging modalities represented different values of renal volumes [Table/Fig-11] [6,10,15,16,19-23]. The mean renal volume calculated in the present study was smaller than that reported in most of the previous studies but it coincided with study carried out in Pakistan [16, 21]. In an autopsy study carried out by Caglar V et al., involving 114 adult males in Turkey, calculated mean kidney volume was 149.7±48.1ml [1]. In living kidney large amount of blood circulates through it thus results of cadaveric or autopsy study cannot be compared with radiological interventions conducted on living subjects [24].

In the present study, left kidney volume was greater than right kidney volume, though statistically insignificant. Best possible explanation

Different geographical studies	Geographical area	Population of study group	Mean renal volume	Imaging modality	Comparison of renal volume with respect to gender	Comparison between right and left renal volume
Okur A et al., [6]	Turkey	152	Right 158±39 cm^3 Left 168±40 cm^3	USG	Male > Female	Left renal volume>Right renal volume
Shin HS et al., [10]	Korea	113	Right 203.26±38.60 cm^3 Left 207.32±37.50 cm^3	CT	--	Left renal volume>Right renal volume
Breau RH et al., [15]	Ottawa, Canada	28	170-186 cm^3	CT	--	--
Raza M et al., [16]	Islamabad, Pakistan	4035	Right 99.8±37.2 cm^3 Left 124.4±41.3 cm^3	USG	Male > Female	Left renal volume>Right renal volume
Rasmussen SN et al., [19]	Copenhagen, Denmark	46	4.3-8.0 ml/kg	USG	No difference	No difference
Emamian SA et al., [20]	Copenhagen, Denmark	665	Right 134 cm^3 Left 146 cm^3	USG	Male > Female	Left renal volume>Right renal volume
Buchholz NP et al., [21]	Karachi, Pakistan	194	Right 70±20 cm^3 Left 82±24 cm^3	USG	Male > Female	Left renal volume>Right renal volume
Cheong B et al., [22]	Texas, United States	150	Right 166±29 ml (male) 130±30 ml (female) Left 168±28 ml (male) 131±33 ml (female)	MRI	Male > Female	--
Rathore RS et al., [23]	Kerala, India	84	Right 130.38±16.82 ml (male) 123.56±19 ml (female) Left 143±20.67 ml (male) 132±21.26 ml (female)	CT	Male > Female	Left renal volume>Right renal volume
Present study	Maharashtra, India	70	Right 94.18±23.68 cm^3 Left 98.07±24.92 cm^3	CT	Male > Female	Left renal volume>Right renal volume

[Table/Fig-11]: Comparison between different geographical studies [6,10,15,16,19-23].

Different geographical studies	Geography	correlation between subject's body weight and renal volume	Correlation coefficient (r)
Okur A et al., [6]	Turkey	Positive linear correlation	r =0.32-0.44
Shin HS et al., [10]	Korea	Positive linear correlation	r =0.649
Raza M et al., [16]	Islamabad, Pakistan	Positive linear correlation	r =0.417 (Right) r =0.385 (Left)
Rasmussen SN et al., [19]	Copenhagen, Denmark	Positive linear correlation	r =0.698
Dinkel E et al., [28]	Freiburg, Germany	Positive linear correlation	--
Soyupak SK et al., [29]	Adana, Turkey	Correlation found	--
Safak AA et al., [30]	Duzce, Turkey	Positive linear correlation	r =0.552 (Right) r =0.511 (Left)
Present study	Maharashtra, India	Positive linear correlation	r =0.323(Right) r =0.434(Left)

[Table/Fig-12]: Comparative account of correlation between subject's body weight and renal volume in different geographical areas [6,10,16,19,28-30].

is that spleen present on left side of abdomen has smaller size than liver on the right side of abdomen thus providing larger space for the growth of left kidney. Also the length of left renal artery is smaller than right renal artery thus raised blood flow through left renal artery leads to relatively larger left renal volume [6]. In most of the studies, researchers determined Left renal volume significantly greater than right Renal volume [Table/Fig-11]. Thus, our study showing greater left renal volume than right renal volume was consistent with most of the previous studies. However, some authors also have reported no perceptible difference between volumes of right and left kidneys [17,19].

Our study revealed larger kidney volume in males (104.96 cm^3) as compared to females (86.21 cm^3) which was found to be statistically significant and it coincided with most of the previous studies [Table/Fig-11]. In contrast to most of the past researches, Rasmussen SN et al., did not notice any remarkable difference in renal volumes in relation to sex [19].

Most of the Past researchers have reported that renal volume showed negative correlation with age of an individual [6,20,25] and this coincided with the present study. Dunnill and Halley considered 68 pair of kidneys for study aged ranging from birth to 90 years and 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. Thus, established an inverse relationship between kidney volume and age [26]. Prospective analysis of data from 1222 autopsies in Legal Medicine Organization of Iran showed that kidney weights declined with age [27]. Buchholz NP et al., reported that all renal dimensions increased with age till the 3rd decade, remained more or less stable through the middle age, then declined beyond the 6th decade [21]. They explained it as there occurs reduction in renal parenchyma with advancing age [20,25]. So, all the above researches favour our finding of inverse correlation between renal volumes with age. In contrast to previous studies, kidney volume was found to increase with advancing age in apparently healthy Bangladeshi people due to an increase in renal sinus fat with age compensating for the decrease in the kidney volume [17]. There was a statistically significant inverse relationship between age of an individual and left renal volume in an ultrasonographic study carried out in Pakistan involving 4035 adults which matches with our study [16].

We observed significantly positive linear relationship between individual's body weight and renal volume (For right renal volume, r =0.323 and for left renal volume, r =0.434) in combined group consisting of males and females in the present study.

Our study is in accord with the studies conducted by most of the researchers [Table/Fig-12] [6,10,16,19,28-30]. Caglar V et al., observed that there exists positive correlation between kidney size and body weight in an autopsy study involving 114 adults [1]. Some researchers commented about failure of getting correct results on comparing autopsy study with radiological interventions conducted on living subjects as large amount of blood circulates through living kidney [24].

Thus, our study fortifies the knowledge of the standard range of computed tomography-based renal volume in study population aged 21 to 79 years. Estimation of renal volume requires the measurement of all the three dimensions of kidney and is slightly time consuming procedure. In clinical practice, body weight can be recorded quickly and this somatic parameter can be easily used to calculate the renal volume in an individual using linear regression equations which was derived in the present study.

LIMITATION

Present study has got certain limitations. Study involved 70 healthy subjects which were free from renal disease. But some of them might have subclinical renal disease which was not evident at the time of evaluation. Moreover present study involved limited number of patients with only two reviewers. Further studies with large number of patients and reviewers are recommended to get more accurate results which authenticate our findings

CONCLUSION

Renal volume showed a positive correlation with the body weight of an individual. Thus body weight, somatic body parameter, can be used to estimate the renal volume. Right and left renal volumes can be calculated simply by our derived linear regression equation using body weight of an individual. Thus, renal volume of an individual acts as surrogate for renal function reserve and can be used as a diagnostic somatic body parameter in nephrologic as well as urological practices.

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