Research Article

Renal volumes by ultrasound and its correlation with body mass index and body surface area in adult population

Maravi P.[1], Khan M.[2], Kaushal L.[3], Goyal S.[4]

[1]Dr. Poornima Maravi, Associate Professor, [2]Dr. Mehrukh Khan, Junior resident III, [3]Dr. Lovely Kaushal, HOD and Professor, [4]Dr. Swati Goyal, Associate Professor; all authors are attached with Department of Radiodiagnosis, Gandhi Medical College, Bhopal, Madhyapradesh.

Corresponding Author: Dr. Poornima Maravi, Associate Professor, Department of Radiodiagnosis, Gandhi Medical College, Bhopal, Madhyapradesh.

Abstract

Context: Renal volume measurements by USG in adult population and its correlation with metabolic indicators like body mass index (BMI) and body mass area (BSA). **Aims:** Renal functions are directly related to the renal dimensions, especially renal volume, which greatly varies with individual phenotype. The Aim of this study is to correlate renal volumes as obtained by ultrasound with Body Mass Index and Body surface area in Adult population with normal serum urea and creatinine. **Settings and Design:** Hospital based, cross sectional study. **Methods and Material:** Total 105 adults presenting in Hamidia Hospital OPD [52 Males (M) + 53 Females (F)] referred for USG abdomen in Radiodiagnosis department were examined by Philips Doppler equipment. Auto-calculated renal volumes were obtained using volumetric software. BMI, BSA were calculated with individual height and weight. All patients presenting in clinical OPDs with symptoms other than abdominal/urinary/renal complains were included. All patients demonstrated normal serum urea and creatinine levels. **Statistical analysis used:** Correlation coefficient (r) and P-values were calculated using excel data tool. **Results:** Age ranges from 20-70 yrs with mean age 43.08 yrs.[(M) = 44.60 yrs, (F)= 42.07 yrs]. Mean BMI and BSA was 26.87kg/m2 and 1.76 m2, (M=26.679 kg/m2, 1.88 m2 and F= 27.059 kg/m2, 1.63 m2). Mean renal volume of right kidney (RK) was 110.34 cm3 and left kidney (LK) was 104.66 cm3 [(M= 117.05(RK), 117.28(LK)], and [F= 103.60(RK), 104.66(LK)].Renal volumes were higher in younger population and in males (M= 118.94 cm3 RK and 49.18 cm3 LK> F=109.21 cm3 RK and 44.28 cm3 LK). **Conclusions:** Renal volumes in adult populations with known abdominal/urinary/renal complains were positively correlated with individual height and weight and so with BMI and BSA. Stronger correlation was noted with BSA and left kidney volumes. These observations can contribute in development of renal normograms in adult population and to assess renal morbidities when variations in above observations is seen.

Keywords: Kidneys; Volume; Nephron

Key message: Renal volumes are better criteria to assess normal renal size rather than single linear measurements (like longitudinal measurement) as kidneys considerably vary in shape. Positive correlation of renal volumes with metabolic indicators like BMI and BSA may suggest that the kidneys are functionally normal, discordance between these parameters and renal size may indicate altered functional state which may need further evaluation.

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Introduction

It is a well known fact that kidneys play an important role in individuals metabolism. Renal measurements are directly proportional to individual's height and weight which again directly influence the renal metabolism [1]. Studies have shown that the renal longitudinal measurement is most important in determining the renal function in normal renal status while renal volume is the most important criteria in determining the renal function in altered renal states like end stage renal diseases [2].

Many studies have provided insight of renal size and renal volume normograms by ultrasound but most of them were either performed on western population or on a small sample size. Many studies have been conducted on Indian population focusing on renal size like renal longitudinal diameter, breadth and parenchymal thickness [2]. However very few studies are there purely focusing on renal volume. We aimed to evaluate the renal volumes of total 210 renal units in adult Indian population in Hamidia hospital (GMC,

Bhopal) by ultrasonographic measurement and establish their correlation with individuals phenotype (height, weight), BMI (body mass index) and BSA (body surface area).

Subjects and Methods

In this Hospital based, cross sectional study, carried out at, Gandhi Medical college and Hamidia hospital, Bhopal, M.P, for 6 months (starting from May 17 to Oct 17), Total 105 adults referred to Radio-diagnosis department for abdominal ultrasound from clinical OPDs were evaluated. Many of these adults attended the OPD for routine health check-up and showed normal renal parameters/USG findings on examination. Rest of the patients who were referred to the department attended the OPD for chronic generalised headache, unilateral or bilateral eye-ache, neck/thyroid swellings, superficial /cutaneous swellings, musculo-skeletal and joint pain, breast and its related complains i,e Other than renal/urinary complains. Written, informed consent was obtained before performing the each examination. Many subjects were non-fasting (post-meal) and none of them were dehydrated. All subjects were examined by Philips HD7XE Doppler equipment.

The age ranges from 20-70 yrs. Total subjects include 53 males and 52 females. Renal volumes were obtained by examining the both kidneys in supine positions. Linear measurements were taken in longitudinal, transverse and AP dimensions (figure 1-3) and auto calculated (volumetric software) renal volumes were obtained. Individual's height (cm) and weight (kg) were recorded, BMI and BSA were calculated using formula BMI=weight (kg)/ height (m2), BSA= 0.016667 x weigh 0.5 x height 0.5 (mosteller formula). Correlation coefficient (r) and p values were calculated using data analysis tool of Microsoft excel to know the significance of correlation.

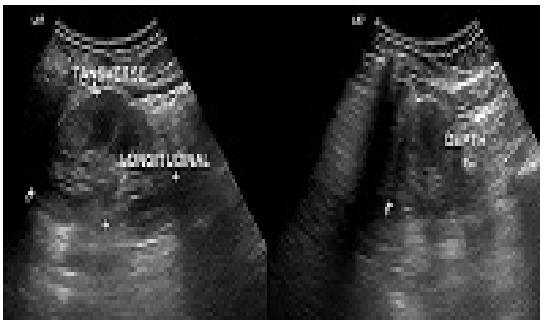
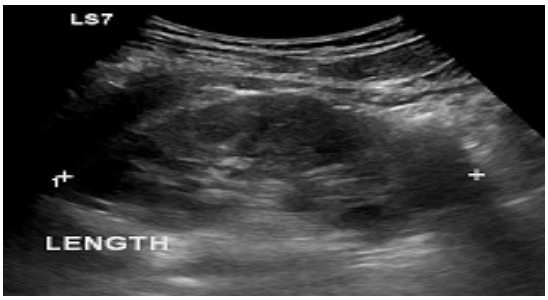


Figure 1: ??????



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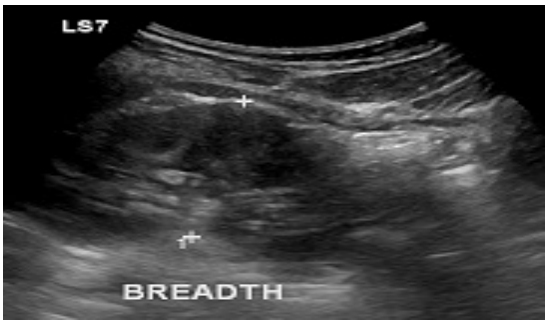

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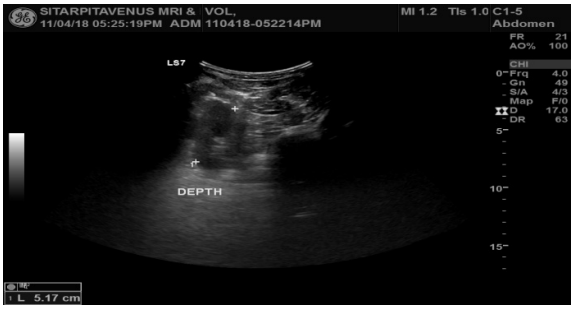


Figure 4:?????????

Inclusion criteria- All adult subjects presenting in department for routine health check up were included. All symptomatic patients with no known/pre-existing renal disease were included. Normal renal status in these patients was cross-checked by documented normal serum urea and creatinine levels (serum creatinine 0.6-1.3 mg/dl and blood urea nitrogen 7-18 mg/dl) in routine blood reports, when available.

Exclusion criteria- Symptomatic Patients showing elevated levels were excluded. Patients with history of pre-existing renal diseases (including diabetes and hypertension) were excluded. Patients showing any features of cortical cysts, mass, hydronephrosis, cortical scars, horseshoe-kidney, ectopic kidney, OR features of medical renal disease on Ultrasonography were excluded. Pregnant women and women who had recently given birth were also excluded.

Results

Total 105 subjects, consisting of 52 males and 53 females were evaluated. The age ranges from 20-70 yrs. Mean age was 43.13 yrs, males (44.60 yr) and females (41.63 yr). In this hospital based, cross sectional study of 105 adult population mean right renal volume was 109.70 cm3 and left mean renal volume was 110.97 cm3 (cumulative mean 111.28 cm3) . Mean BMI and BSA was 26.86 kg/m2 and 1.75 m2.

Male population show mean right renal volume of 118.71cm3, left renal volume 119.16 cm3 with mean BMI and mean BSA 26.7 kg/m2 (preobese) and 1.88 m2 respectively. Mean right renal volume in female population was 102.59 and left renal volume was 104.66. Mean BMI and Mean BSA was 27.05 kg/m2 (preobese) and 1.64 (Table 1).

Table-1: Showing overall male and female distribution of renal volume, height, weight, BMI and BSA

Gender	Subjects	Median Age (yrs)	Median RK (cm3)	Median LK (cm3)	Median Height (cm)	Median weight (kg)	Median BMI (kg/m2)	Median BSA (m2))
Males	53	46	112	114	170	76	26.7	1.88
Females	52	41	98.2	99.3	154	64	27.059	1.67
Total Population	105	43.13	109.70	110.97	161.39	70.00	26.869	1.75

Age-group 51-60 yr consist of maximum number of patients (30) and 61-70 yr consist of minimum number of patients (6) of patients. Highest volumes of kidneys were noted in 20-30 yrs of age group (youngest age group) (RK= 126 cm3, LK=129 cm3) in male population. Highest (median) BMI was noted in 28.23 kg/m2 (preobese) in age group 51-60 yrs in female population and highest BSA 1.93 m2 was noted in 20-30 (youngest age group) yrs of age group in male population. Renal volumes were highest in youngest male population with highest BSA which depicts direct relationship with renal volumes and BSA.

Overall volumes of left kidney were higher than right kidney. Renal volumes were higher in male population than female population. Mean renal volumes were higher in males than females.

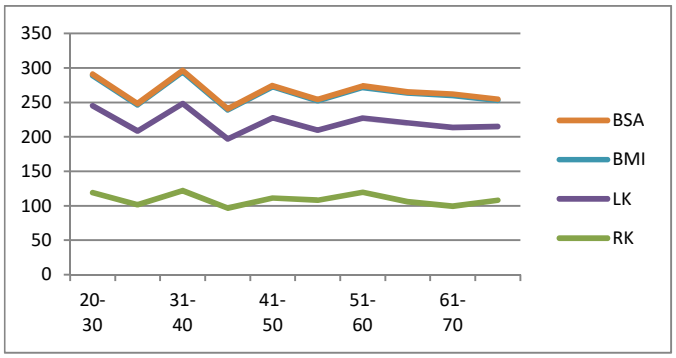
Mean height was 1.6157 m and mean weight was 70.19 kg. Mean height was 1.6881 m in males and 1.3514 m in females. Maximum height (178 cm) in 41-50 yrs age group in male population. Mean weight was 75.88 kg in males and 61.31 kg in females. Highest weight was seen in age group 61-70 yrs (80 kg). Mean BMI was higher (overweight) in females however

Mean BSA was lower than males. Negative correlation seen between renal volumes and advancing age (stronger with LK). As the age advances renal volumes tends to decrease .Maximum peak of renal volumes were noted at age group 20-30 yrs, then slow decline towards advancing age. Mean BSA were also following declining pattern with advancing age however no significant correlation seen. BMI appear comparatively static with advancing age (Table 2).

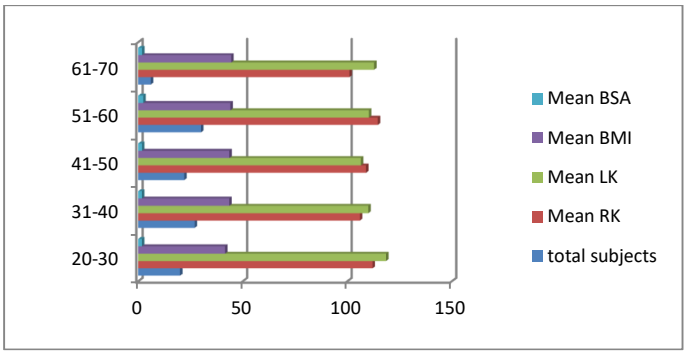
Table-2: Showing distribution of renal volumes, height, weight, BMI and BSA in male and female population in different age groups.

Age group (age in years)	Gender	Subjects	Median age	RK (cm3)	LK (cm3)	Height (cm)	Weight (kg)	BMI ((kg/m2)	BSA (m2)
20-30	M	12	25	126	129.5	173.5	77	25.85	1.935
	F	8	28	108	113.5	154	59	24.65	1.59
31-40	M	10	33	113	119.5	171.5	79	26	1.93
	F	17	36	98.5	99.25	155	65.5	27.5	1.68
41-50	M	7	45	105	114	178	79	25.4	1.96
	F	15	46	98	99	155	65	27.1	1.67
51-60	M	19	55	102	104	160	72	28	1.81
	F	11	55	95.7	112.5	153	67	28.236	1.68
61-70	M	5	65	95	118	171	80	26.7	1.89
	F	2	63.5	95	97.5	152	59.5	25.75	1.67

Linear diagram 1- showing distribution of renal volumes, BMI and BSA in different age groups



Bar diagram 1-Showing mean values of renal volumes, BMI and BSA in different age groups



Taller the individual, more the renal volume, however after reaching peak heights at 166-170 cm3, Renal volumes tends to decrease, that suggest renal volumes are higher in taller individuals however relationship is not linear, after reaching to certain height e.g. 166-170 cm3 in this case, renal volume is no larger. Maximum weight was 79 kg at 166-170 cm however tends to decrease after that range.BSA correlates with height ranges strongly with Max BSA (1.945 m2) at height range of 176-180 cm3 thereafter decreases. BMI (29.15 kg/m2 at 161-165 cm) doesn't appear to be directly correlating with height, weight and renal volumes (Table 3).

Table-3: Height wise distribution of renal volume, BMI and BSA

Height (cm)	Mean weight (kg)	RK volume (cm3)	LK volume (cm3)	BMI (kg/m2,)	BSA (m2)
145-150	62.5	92.5	93.7	28.3	1.61
151-155	65	98	100.15	27.65	1.67
156-160	69	102	105.4	27.55	1.74
161-165	78	111	113.5	29.15	1.87
166-170	79	120	126.5	27.5	1.925
171-175	78	114	111	26.4	1.93
176-180	78.5	118	119	24.55	1.945
181-185	77.5	118	120	23.65	1.97

As the weight increases renal volumes tends to increase (maximum renal volumes RK=131 cm3, LK=142 cm3 at weight range of 86-90 kg). BMI and BSA tend to follow the same pattern (maximum BMI=31.2 kg/m2 [obese class 1], BSA=2.0 m2). Max height (175.5 cm) was seen at weight range 81-85 kg, thereafter decreasing (Table 4).

Table 4: Weight wise distribution of renal volume, BMI and BSA

Weight (kg)	Median Height(cm)	Median RK volume(cm3)	Median LK volume(cm3)	Median BMI(kg/m2)	Median BSA (m2)
50-55	154.5	97.5	98.4	22.55	1.515
56-60	156.5	108	105.4	24.5	1.59
61-65	154	99	99.2	26.2	1.64
66-70	155	97.7	99.15	28.1	1.705
71-75	160	109	112.4	28.1	1.79
76-80	173	108	117.5	25.75	1.93
81-85	175.5	120.5	125	26.8	1.97
86-90	168	131	142	31.2	2.0

K Y Kang et al showed maximum mean renal volumes were found in Korean population (158 cm3), followed by Danish (146 cm3), Mexican (134 cm3) and Caucasian population (130 cm3). Sampled Indian population shows smallest renal volume (111.28 cm3) when compared to the people of other ethnicity (Table 5).

Table-5: Showing comparisons of renal volume in different ethnic population.

Authors	Ethnicity	Number	Renal volume
Emamian et al	Danish	665	146
J.OyuelaCarassco et al	Maxican	153	134
Williams et al	Caucasians	-	130
K Y Kang et al	Korean	125	158

According to the international classification based on BMI, maximum subjects 70 (66.66%) fall under category of preobese population (25-29.99 kg/m2) while only 23 (21.90 %) individual fall under normal weight category (18-24.99 kg/m2). 12(11.42 %) individual fall under category of class 1 obese with BMI >30 kg/m2 (table 6).

Table-6: WHO classification for adults according to BMI 15

BMI (kg/ m2)	Classification	Subjects
<18.50	Underweight	0
18.50-24.99	Normal weight	23
25-29.99	Pre-obese	70
30-34	Class I obese	12

Discussion

Importance of kidneys in microcellular/sub-cellular metabolism has become clearer during the passing year. The biochemical disturbances can be broadly divided into those related to humoral function of the kidney and those presumably related to failure of detoxification or excretion of metabolites. Vasopressor and vasodepressor substances and erythropoietin represent humoral factors elaborated by the kidney that may have effects on other organs when renal function is compromised [3]. The number of nephrons in a kidney correlates with the physical dimensions and size of the organ [4]. The examination of a kidney's size may be a clue to renal function [5]. Studies have shown that volume measurements may predict single renal glomerular filtration rate better than renal length measurements [6]. In renal sonograms, renal volume correlated better than volumes of the central echogenic area and the renal parenchyma with height, weight, and total body area in adults [7]. The importance of accurate measurement of renal size cannot be overemphasized because recent studies have suggested that the size of the allograft, or the ratio of the kidney weight to the donor body weight, have a direct positive relationship to graft survival [8,11].

Our study corroborates the work done in Australia [1], UK [7] and Denmark [11] in normal subjects. Our study demonstrates that the left kidney is larger than the right kidney, and that kidneys are larger in males than in females. Reasons have been postulated for the bigger size of left kidney is that because the spleen is smaller than the liver, the left kidney has more space for growth. Another explanation is that because the left renal artery is shorter and straighter than the right one, increased blood flow in the left artery may result in relatively larger size [1,2,10]. The mean renal volumes we observed were slightly different from those reported in other studies [1,7,10] possibly due to difference in ethnicity.

We also show that there is negative correlation between renal size and patient age. As the age advances the renal volume tends to decrease (left kidney volumes tends to decrease more than right kidney with (r=0.111). This is in support of studies done by Emamian SA, and Justo Oyuela-Carrasco, et al [10.11]. The explanation for this is that the number of nephrons per normal kidney, which varies between 400,000 and 1,000,000 nephrons per kidney, diminishes with advancing age [11]. Previous research work have shown that Renal volume is the most precise measurement of renal size and tends to show the positive correlation with height, weight BMI and BSA [10]. Our study showed positive correlation of renal volumes with individual's height (r=0.15 for RK and 0.32 for LK) and weight (r=0.20 for RK and 0.34 for LK). Positive correlation were seen with different age groups and individuals weight (r=0.10). Positive correlation of BMI with renal volumes seen within particular age groups {(namely age group 20-30 yrs (for RK r=0.76 and LK r=0.83}) which is in accordance of most of the studies done previously [3,11]. Positive correlation of renal volumes were shown with BSA (left kidney shows stronger correlation) as in study of Nyengaard JR, Bendtsen TF who studied relation of glomeruli number and size with age, renal weight and individuals body surface area [4].Cumulative renal volume showed positive correlation with BSA and BMI (r=0.31248, p=0.001177 and r=0.210603, p=0.031051). We also found that BSA has stronger correlation with renal volume when compared to BMI (weaker correlation).

~66.66% adults in this population fall under category of pre-obese according to the WHO classification, however it is important to remember that BMI measurements do not make distinctions between whether the subject is male or female, or have large or small body frame, or have high muscle mass. For this reason, BMI cannot be taken as true indicator of obesity at its own [14, 15]. Regarding this fact some modification in lifestyle along with importance of regular physical activity/exercise may be emphasized for this sample population.

The mean BSA in males was significantly higher (1.87 m2) than in females (1.63 m2), which may also explain the higher mean renal volume observed in males Also when comparing mean renal volume of this population (111.28 cm3) with other ethnicities, renal volumes in this study were significantly smaller than Caucasian, Danish, Maxican and Korean population [1]. Though the sample size in this study is too small to represent entire Indian population, these parameters may be considered during development of new normograms for renal volumes referencing Indian population. Above results were due to wide variation of anthropometric data between these population.

Conclusion

In conclusion, as renal volume is the most precise measurement of renal size, we established values of renal volume in adult population by USG (emphasizing on normal renal status by excluding any subject showing renal morbidities on USG /history/examination with including all subjects who showed no evidence of any known medical/surgical/functional or congenital renal disease). This study has shown that renal size on the left is larger than on the right. Also female patients have smaller

kidneys than males. The renal volumes show significant positive correlation with BMI and BSA, however stronger correlation seen with BSA. Above data may also contribute for developing renal normograms when assessing renal diseases in Indian population. However, need for such studies with larger sample size is recommended. Some modification in lifestyle with importance of physical activity/ exercise may be suggested for sampled population (Pre-obese) according to the WHO classification; however these criteria are relative and not absolute.

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