ORIGINAL ARTICLE

ULTRASONOGRAPHIC ASSESSMENT OF RENAL SIZE AND ITS CORRELATION WITH BODY MASS INDEX IN ADULTS WITHOUT KNOWN RENAL DISEASE

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Background: Many conditions affect renal size. To evaluate abnormalities in renal size, knowledge of standardised values for normal renal dimensions is essential as it shows variability in the values of normal renal size depending on body size, age and ethnicity. Ultrasound, being an easily available, non-invasive, safe and less expensive modality, is widely used for evaluation of renal dimensions and repeated follow-ups. The objectives of this study were to determine renal size by ultrasound in adults without any known renal disease, and to determine the relationship of renal size with body mass index. **Methods:** Study was conducted in the Department of Diagnostic Radiology, Shifa International Hospital and PIMS Islamabad. Renal size was assessed by ultrasound in 4,035 adult subjects with normal serum creatinine and without any known renal disease, between November 2002 and December 2010. Renal length, width, thickness and volume were obtained and mean renal length and volume were correlated with body mass index and other factors like age, side, gender, weight and height of the subjects. **Results:** Mean renal length on right side was 101.6±8.9 mm, renal width 42.7±7.1 mm, and parenchymal thickness 14.4±2.9 mm. On left side, mean renal length was 102.7±9.2 mm, width 47.6±7.0 mm, and parenchymal thickness 15.1±3.1 mm. Mean renal volume on right was 99.8±37.2 cm^3 and on left was 124.4±41.3 cm^3. Left renal size was significantly larger than right in both genders. Relationship of mean renal length was significant when correlated with age, side, gender, height and weight, and body mass index. Renal volumes also showed a similar relationship with side, gender, height and weight, and body mass index; but with age such a relationship was seen only for left kidney. **Conclusion:** Pakistani population has mean renal size smaller than reference values available in international literature. Renal length and volume have a direct relationship with body mass index. Mean renal size is related to the side, age, gender, height and weight as well.

Keywords: Body mass index, Renal size, Ultrasound

INTRODUCTION

Renal size and function reflect the health of the kidney.[1] Change in renal dimensions is an important sign of renal disease as kidney sizes are significantly influenced by congenital anomalies, urinary tract diseases,[2] systemic diseases, micro and macrovasular diseases,[1] and neoplasia, etc.

Many modalities and techniques have been used for renal evaluation, especially in terms of size, but no single method is universally accepted by radiologists for renal size assessment[3] as all radiological methods are associated with prediction errors.[4] Ultrasonography (US) replaced standard radiography[5] and has become the standard imaging modality in the investigation of renal diseases[6] due to its non-invasive nature and easy availability[7]. It offers excellent anatomical details, requires no special preparation of patients, is readily available, and does not expose the patient to radiation or contrast agents. Renal US is used to determine the site and size of the kidneys and to detect any focal renal lesion.[6] It also helps to evaluate pertinent anatomy and pathology especially during surgery in case of intraoperative US.[8] In a study on donor kidneys, the measurements obtained by using US were more accurate than those based on plain radiographs, excretory urograms or renal angiograms.[5] However underestimation of sonographic renal volume is found when compared with measurements by computed tomography[4,9] and magnetic resonance imaging.[10] Still, because of its safety, low cost and easy availability, US is widely accepted and considered as the tool of choice especially where repeated examinations are required.[11] However, reproducibility is poor as it is operator dependent.[4,9]

Renal size can be determined by measuring renal length, renal volume and cortical volume or thickness.[4] Renal length and volume measurements are clinically relevant, serving as surrogates for renal functional reserve, and are used frequently as the basis for making clinical decisions. Serial measurements can also provide information regarding disease progression or stability.[12] In subjects with normal renal function, an important measurement of renal size is longitudinal length, however, the renal parenchymal volume is the more exact US parameter in end-stage renal failure.[13] Renal volume is correlated with subject's height (ht), weight (wt) and total body area, but it is not a precise method due to high inter-observer variations.[4,9]

As kidney size abnormalities are reflective of many renal diseases, it is valuable to have a set of standard US measurements for use when these patients are examined. As opposed to information on renal measurements in children and infants, only a few reports have been published on sonographic renal measurements in adults.[5] The presence of close relationship between kidney sizes and functions has stimulated the research related to renal sizes for different ethnic groups and body sizes, which are known to be helpful in diagnosis of kidney diseases. Thus aim of this study is to help establish standardised data of normal renal dimensions in our population and also to prove the hypothesis that mean renal size has a direct relation with body mass index (BMI).

MATERIAL AND METHODS

This prospective observational study was conducted in Diagnostic Radiology Department of Shifa International Hospital and PIMS Hospital Islamabad. Four thousands and thirty-five subjects above 18 years of age having normal renal function tests and without any known renal disease were recruited, who underwent an abdominal or genitourinary diagnostic ultrasound, between November 2002 and December 2010. Pregnant females, subjects with known diabetes and hypertension and the patients who were unable to change posture for accurate assessment of kidneys during US examination were excluded from the study.

Same observer performed examination every time to avoid any inter-observer variation. Height was taken in centimetre (Cm) and weight in kilogram (Kg), and BMI was calculated.[2] The patients required no prior preparation. All the US examinations and measurements were performed using two-dimensional Real Time US machine with curvilinear transducer of 3.5–6 MHz frequencies, equipped with electronic callipers. Once the kidney was located, the transducer was rotated slightly to determine the longest renal axis and renal length was measured as the maximum bipolar dimension in longitudinal plane which showed central sinus echoes the best with the renal parenchyma evenly distributed all around the central sinus. The transducer was then rotated 90 degrees to the longitudinal axis and the transverse section was obtained at the level of the renal helium. Renal width was measured as the maximum distance between medial and lateral borders of kidney. In the same plane, renal thickness or depth was also measured as the distance between ventral and dorsal surfaces of the kidney. The parenchymal thickness was measured as the distance between outer renal margin and renal sinus in transverse plane. Mean of three readings was taken for each of them. Longitudinal dimension of kidneys in millimeter (mm) was taken as absolute renal length (ARL). Relative renal length (RRL) was taken as ratio of ARL and subject's body height in Cm. The volume of the entire kidney was calculated using the mathematical formula:

$$\frac{\text{Length (Cm)} \times \text{width (Cm)} \times \text{depth (Cm)}}{2}$$

Correlation of renal length and volume with BMI and also with age, gender, height and weight of the subjects were determined.

Data was analysed on SPSS-11. Descriptive statistics were applied on the available data. Mean±SD was presented for age, ARL, renal width, renal parenchymal thickness and volume. Frequencies and percentages were computed for gender and age groups. Pearson's correlation coefficient (r) was computed to assess correlation of renal sizes with BMI, age, weight and height. Scatter graphs were also made to assess the linear relation ship of BMI, age, height and weight with ARL, RRL and renal volume for both sides. Comparative analysis between dimensions of left (LT) and right (RT) kidney, renal sizes of males and females were done by means of t-test and difference among the two groups were considered to be significant if $p<0.01$.

RESULTS

Total number of subjects included in this study was 4,035. Out of them 9 subjects were given suspicion of a tiny renal concretion but had no obstructive signs. There were 1,961 were male (48.6%) and 2,074 (51.4%) females. Mean age was 44.4±15.2 years, with the majority lying in the 4th and 5th decade of life. Height of the subjects ranged from 120–192 cm with a mean of 172.6±6.9 Cm for men and 155.2±5.9 Cm for women. Similarly, weights ranged from 36–137 Kg with a mean of 76.3±14.4 Kg for men and 67.1±13.9 Kg for women.

Mean ARL for RT kidney was 101.6±8.9 mm, renal width 42.7±7.1 mm and parenchymal thickness 14.4±3.0 mm. For LT kidney these readings were 102.7±9.2 mm, 47.6±7 mm and 15.1±3.1 mm for mean ARL, width and parenchymal thickness respectively. RRL was 0.62±0.06 on RT and 0.63±0.06 on LT. Mean renal volume on RT was 99.8±37.2 Cm^3 and 124.4±41.3 Cm^3 on LT. Statistically significant difference was found between dimensions of RT and LT kidneys, with LT being slightly larger than RT in ARL, renal width, parenchymal thickness, RRL and renal volume ($p<0.01$). All these parameters were statistically higher in males as compared to females ($p<0.01$). Mean renal sizes for males and females are presented in Table-1.

Mean longitudinal renal length showed a gradual decrease from sixth decade onwards and on correlation of ARL with age, we found a significant negative ($p<0.01$) but a relatively weak linear relationship between the two, in both genders bilaterally. Scatter plot showed majority of the scores being scattered above or below the linear regression line but still weakly obeying the linear relationship. Value of 'r' for RT kidney was -0.221 and -0.210 for LT. A statistically significant, negative but weak linear relationship was also seen when age was correlated with RRL bilaterally, LT renal volume and left renal width (p<0.01). RT renal width, volume and bilateral parenchymal thicknesses did not show any significant correlation with age (p>0.01).

As the height of subjects increased a significant increase in ARL and renal volume was seen, showing a positive but a weak linear relationship. This was found to be comparatively more between 'height and renal volume' than between 'height and ARL'. Value of 'r' was 0.352 on RT and 0.412 on LT for renal volume and 0.281 on RT and 0.298 on LT for ARL when height was correlated with these variables.

A significant negative correlation was seen with RRL on both sides with 'r' of -0.444 and -0.417 for RT and LT side respectively.

As seen between height and renal size, a similar significant positive relationship was found on correlation of subject's weight with ARL and renal volume (p<0.01). Value of r was 0.417 and 0.385 on RT and LT side respectively for renal volume and it was 0.365 and 0.397 for ARL on Right and Left respectively. No statistically significant correlation was seen with RRL on either side ($p \geq 0.01$).

With increase in subject's BMI, a significant increase in ARL and renal volume was also seen. Mean BMI was 26.8±5.45 Kg/m^2 (range: 14.8–55.1). A significantly positive but weak linear relationship was found when ARL and BMI were correlated for both kidneys. Value of 'r' was 0.192 and 0.211 for RT and LT side respectively.

Renal volume showed a similar relationship with BMI. Calculated 'r' was 0.192 and 0.118 for RT and LT side respectively. RRL also had a positive relationship with BMI, which was comparatively more than that of ARL and renal volume with BMI (Table-2).

Table-1: Renal dimension in males and females

Parameters	Males (n=1,961)				Females (n=2,074)			
	Right kidney		Left kidney		Right kidney		Left kidney	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Renal length (mm)	103.2±8.9	70–131	104.6±9.1	80–137	100.0±8.59	77–131	100.9±8.97	80–126
Renal width (mm)	45.3±7.3	19–74	50.5±6.6	23–69	40.2±5.96	23–69	44.9±6.27	26–65
Renal volume (cm^3)	113.0±39.4	27.2–270.8	140.7±41.5	30.8–246.3	87.4±30.14	30.8–246.3	108.8±34.8	35.9–251.3
Parenchymal thickness (mm)	9.0±3.1	29.0-5.1	15.8±3.2	8.0–29.0	13.8±2.64	8.0–29	14.5±2.8	27–14.5
Relative renal length	0.60±0.05	0.45–0.81	0.6±0.05	0.49–0.85	0.65±0.056	0.49–0.85	0.65±0.059	0.82–0.65

Table-2: Correlation coefficients between BMI and renal lengths, volume and parenchymal thickness (n=4035)

Parameters	Pearson Correlation Coefficient	
	Right kidney	Left kidney
Renal length	0.19**	0.21**
Renal volume	0.11**	0.19**
Relative renal length	0.36**	0.38**

**Correlation is significant if p<0.05 level (2-tailed)

DISCUSSION

Fear of undergoing any invasive investigation makes the patients reluctant to undergo a test comfortably. Among all the imaging modalities, US has been regarded and preferred as an imaging technique of choice in most of the clinical surveys for being non invasive, safe, reliable, cost effective and easy availability, even though underestimation has been noted in calculated renal volumes by US.

One of the very important and easily reproducible parameter as an indicator of renal function is renal size that shows variations with age, gender, ethnic backgrounds, height, weight and BMI. Many congenital and acquired diseases directly or indirectly significantly affect renal dimensions in all age groups, thus when considering renal size as an indicator for renal function in an individual we have to keep in mind not only the effect of diseases on kidneys but also the relationship of normal renal size of an individual with different factors as mentioned above.

Standard parameters used in routine US renal examinations are longitudinal renal length, renal width and renal parenchymal thickness in mm or cm. Additional measurements acquired using these three parameters include renal volume, ARL and RRL based upon their correlation with subject's height, weight, BMI, age etc. Even the most precise assessment of abnormalities in renal size would require measurement of renal volume or even parenchymal volume in relation to sex, weight, or total body area, but such calculations are not clinically practical.[5] It is rarely included as an indication for intervention due to high inter-observer variation and difficulty in measuring renal volume but it has shown to be a more sensitive method of detecting renal abnormality than any single linear measurement and correlated better with renal mass.[4, 9] In autopsy studies, kidney volume has been shown to correlate well, although indirectly, with the number of functioning nephrons.[9] In contrast to renal length, renal volume has received little attention in the literature as a parameter for clinical follow-up because measurement of renal length is easy. For everyday situations, measurement of renal length is therefore recommended. The small difference and acceptable standard deviation indicate that renal length can be measured with the subject either supine or prone. Thus renal length measurement should be preferred to renal volume estimation because of lower observer variation; more over it is reliable, simple, practical, reproducible measurement of renal size.

We calculated these measurements to find normal values for our population to help standardize a criteria to be used in clinical assessment of certain disease processes largely relying on renal dimensions and thus to reduce any missed or over-diagnosis of a disease in practice. Secondly, aim was to show that BMI had direct relationship with renal size, as proved in few of the comparable studies in recent past.

Normal renal length ranges from 97–112 mm in different populations dependent upon their age groups, gender, height, weight and ethnic backgrounds.[5,11,14–18] Our study showed the mean renal length of 102 mm in Pakistani population, which lies in almost the same range as that of Nigerians,[16] Jamaicans[17] and Malaysians[18] but is relatively shorter as compared to population residing in Denmark, Croatia and USA[5,14,15].

We observed that LT kidney was significantly larger than RT in length, width, parenchymal thickness and volumes. The same has been reported by other workers,[5,14,17–19] while Buchholz NP *et al*[11] observed no significant difference between RT and LT renal length; however RT kidney was shorter in cortical thickness, width and volume as compared to LT. Similarly no demonstrable difference was seen between RT and LT renal volumes by Rasmussen SN et al.[20] Larger value for RRL on left kidney was also reported by Miletic D, *et al*,[14] as in our study.

Probably because of difference in height or body size, renal sizes have been found slightly larger in males in most of the studies.[4,5,11,14,16,18,19,21] The same was observed in current study, that showed a statistically significant larger kidney sizes including volume, ARL, RRL, width and parenchymal thickness in males. Akpinar IN *et al*[21] found a lower RRL in males as compared to females. In contrast, Miletic D *et al*[14] did not find any significant difference between RRL. Many authors have reported no difference in the length of kidneys in the two genders, as a study from Japan[22] and that by Rasmussen SN, *et al*[20].

In children, there is a close relationship between linear growth and kidney length,[23] that indicates that kidney length can be used as a growth parameter in children. Kidney reaches its mature size at age 20–29 years and remains relatively unchanged until the 6th decade of life. Studies have shown that aging leads to progressive decrease in kidney size, after middle age[11,14,19,21] at rate of 0.5 Cm per decade, especially due to a reduction of about 1% per year in blood flow after the third decade[24]. We also noticed a significant negative, but relatively weak, linear relationship between renal lengths (ARL and RRL) with increasing age in both genders. This decrease in renal size became more consistent from 6th decade onwards. In studies by Buchholz NP *et al*[11] and Emamian *et al*[5] renal volume showed a significant decrease with age which probably was totally due to reduction in parenchymal volume.

RRL had shown to be a better index for estimating kidney length as it eliminates variations related to subject's height and gender in some studies[14] especially when estimating and comparing renal sizes in different individuals. However in geriatrics RRL could not completely eliminate variations and ARL had been recommended for renal measurements.[21] The current study found a significant negative relationship of age with RRL, though comparatively less marked than with ARL.

Rasmussen SN, *et al*[20] has reported the total renal volume to be the most accurate when correlated with the body weight; and normal values of total renal volume per Kg of body weight were 4.3–8.0 ml/Kg. In normal subjects, the smallest kidney's volume should not be less than 37% of the total renal volume.[20] In studies by Emamian SA *et al*[5] and Fernandes MM[19] a significant correlation was seen between renal length and height bilaterally; while some authors concluded that renal length is not associated with body's height, but with subject's weight,[16] while some others believed that lengths and widths of kidneys were not associated with height in either genders[17]. Our data showed a significant positive relationship when subject's height and weight were correlated with renal volume and length in both genders. This correlation was comparatively stronger between renal volume and subject's height and weight. This finding has been supported by many workers.[5,11,19]

The renal length and renal volume have been found to show a good accordance with BMI.[11] This was shown in our study as well where renal length showed a stronger correlation than renal volume. An additional correlation of BMI was seen with RRL that was slightly stronger than the other two parameters.

CONCLUSION

Mean renal sizes in Pakistani population are significantly smaller than reference values available in literature from American and European populations. Left kidney is significantly larger than Right and larger renal sizes are seen bilaterally in males as compared to females. A direct relationship between BMI and renal size is seen in Pakistani population. Much stronger correlation is seen between BMI and RRL, followed by ARL and renal volume respectively.

RECOMMENDATIONS

While performing ultrasound, dependability of renal size on age, gender and BMI has to be considered by the radiologist or sonologist so as to differentiate between a pathological and a normal sized small or large kidney. Use different parameters for the right and left side or in male and female.

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