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Ultrasonographic measurement of renal size among normal adults in Abuja, North-central, Nigeria

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Many renal disorders are associated with changes in the size of the kidneys, normative standards for assessing renal size is essential as it shows variability in the values of normal renal size depending on body size, age and ethnicity and for comparison when examining renal disease. Ultrasound is usually the first imaging modality used in evaluating the kidneys for pathology. The aim of this study is to determine the renal size of normal adult population. This was a prospective cross sectional study conducted over a period of 10 months (January-October 2016) on the kidneys of 390 normal adults aged >18 years. The length, width, depth, volume, cortical thickness and parenchymal thickness of both kidneys were measured using ultrasound. The mean right and left renal size was 139±34.2cm$^3$ and 173.7±13.5cm$^3$ respectively. The difference in size was statistically significant. In males, the mean right renal size was 140.2±33.7 cm$^3$ while the mean left renal size was 183±48.9cm$^3$. In females, mean right renal size was 138.6±34.8 cm$^3$ while the mean left renal size was 164.3±47.7cm$^3$. There was a positive correlation between renal size and age, side, body mass index (BMI) and body surface area (BSA). Normative values of renal size in an adult Nigerian population have been established. Renal size correlated with age, sex, BMI and BSA. Body habitus, age, sex, and side should be taken into consideration when reporting the renal size of normal adults.

Keywords: Ultrasound, Renal size, Normal, Adults, Abuja.

INTRODUCTION

The measurements of renal size in a patient are useful diagnostic parameter for the urologist and the nephrologist. Renal size may be an indicator for the loss of kidney mass and therefore, kidney function (Shcherbak 1989; Guzman et al., 1994). Since several disorders ranging from renal infections/inflammations, nephrologic disorders, diabetes mellitus and hypertension (Montague et al., 1982; Hiraoka et al., 1996; Yamada et al., 1992) affect renal size, it is therefore necessary to first establish normal values of renal size for comparison when evaluating renal diseases. Normative standards for assessing renal size have been developed and are widely used in clinical circumstances (Blane et al., 1985; Dinkel et al., 1985; Erwin et al., 1985; Han and Babcock 1985; Haugstvedt and Lundberg 1980; Holloway et al., 1983; Rosenbaum et al., 1984). However, renal size depends on different factors, including gender, body size and body mass index. Ethnic differences and perhaps partly due to the above, variation in sizes are expected (Oyuela-Carrasco et al., 2009; Buchholz et al., 2000; Arooj et al., 2011; Barton et al., 2000; Okoye et al., 2005) from one geographical location to another confirming the need for regions to develop their own nomogram of renal sizes. While data on normal ranges for renal dimensions are available from Western literature (Emamian et al., 1993; Cheong et al., 2007; Pruijm et al., 2013) the information...
available in the West may not be extrapolated to our population since the renal size may differ between ethnic groups and according to body size (Emamian et al., 1993; Wang et al., 1989).

Ultrasonography estimation of renal sizes is cheap, accessible, non-invasive and forms an integral part of the clinical evaluation of normal as well as diseased kidneys (Gavela et al., 2006; Ablett et al., 1995). It offers excellent anatomical details requires no special preparation of patients, and does not expose the patient to radiation or contrast agents and has largely replaced intravenous pyelogram as the first modality for the evaluation of the Kidneys. Renal size play an important role in decision making for renal biopsy, renal transplant or avoiding immunosuppressive therapy (Ablett et al., 1995). Other imaging modalities for evaluation of renal sizes include computed tomography and magnetic resonance imaging (Cheong et al., 2007; Bakker et al., 1999).

There is no literature of normal renal size estimation by ultrasound in normal adults in the area of study Abuja. Therefore, the aim of this study is to determine the renal size of apparently healthy adult population and the relationship of renal size with age, sex, side, body surface area and body mass index.

**Study Area**

The study was carried out at the Radiology department of University of Abuja Teaching Hospital, Gwagwalada, FCT, Abuja. University of Abuja Teaching Hospital (UATH) is located in Gwagwalada, Gwagwalada area council in the Federal Capital Territory of Nigeria; it is a 350 beds hospital with facility for expansion to 500 beds.

**Study Background and sample size**

\[ N = \frac{Z^2 \cdot p \cdot q \cdot (1-q)}{d^2} \]

where

- \( n \) = Minimum sample size
- \( Z \) = Standard deviation (constant of 1.96 corresponding to 95\(^{\circ}\) confidence interval).
- \( P \) = Proportion in target population estimated to have a particular characteristics.

Therefore, \( n = 1.96^2 \times 0.5 \times 0.5 / 0.05^2 = 384.16 \)

The total number of patient scanned was 390.

**METHODOLOGY**

Renal ultrasound measurements were performed on 390 consecutive normal volunteers with no history of kidney pathology who came for routine medical examination at radiology department, University of Abuja Teaching Hospital Gwagwalada, Abuja. Study inclusion criteria were normal adult patients between ages 18-70 years with no history of renal pathology. Pregnant female, diabetic patient, hypertensive patient, patients who had history of previous surgical operation or trauma to their kidneys, and any renal congenital anomalies and other pathology observed during ultrasound examination were excluded from the study. Before proceeding to ultrasound scanning, brief history was taken, the procedure was explained to the respondents, and their consent obtained. All renal scans were done with EMP G70, China ultrasound scanner using a 3.5 MHz curvilinear probe. Clear gel was applied on the patient skin over the area to be scan. Images were obtained in longitudinal and transverse view in supine and prone position holding their breath during image accusation. The Same observer performed examination every time to avoid any inter-observer variation. Renal length, width, depth, volume, cortical thickness and parenchymal thickness of both kidneys were measured and renal size estimation was obtained by multiplying the first three variables (length x breath x depth x 0.523).

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 a longitudinal plane in cm. Renal width was measured as the maximum distance between medial and lateral borders of kidney almost perpendicular to the longitudinal length in cm. The transducer was then rotated 90 degrees from the longitudinal axis and the transverse section was obtained at the level of the renal hilum. In the transverse plane, renal thickness or depth was measured as the distance between ventral and dorsal surfaces of the kidney. Cortical thickness was measured from the outer border of the renal cortex to the outer border of the medullary pyramid in cm. The renal parenchymal measurement was taken from the outer renal cortical margin to the outer margin of the renal sinus echoes in mm. Three measurements of the renal parenchymal thickness from each side of the upper, lower, and middle poles were obtained and the mean recorded for each kidney. In addition, the age, sex, body surface area (BSA)(m2) = weight (kg)\(^{0.425}\) x height (cm)\(^{0.725}\) x 0.007184 and body mass index (BMI) (kg/m\(^2\)) =weight (kg)/height\(^2\) (m) of the respondents were taken and recorded.

**Data Analysis**

Data were analysed using SPSS 19.0 software. Mean±SD was presented for age, renal length, renal width, cortical thickness, renal parenchymal thickness, and volume. Frequencies and percentages were
computed for gender and age groups. Pearson's correlation coefficient ($r$) was computed to assess the correlation of renal sizes with BMI, BSA, age, side. 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 $p<0.05$.

The study was approved by the Ethical Committee of the hospital.

RESULTS

A total of 780 kidneys of 390 consecutive adults were scanned comprising of 155 (49.5%) males and 197 (50.5%).

The mean age for the subjects was 37.1±12.6. The mean age of females was 39±12.9 and males were 35±11.9. This was not statistically significant ($P>0.05$). The mean height, weight, BMI, and BSA are 1.6±0.09, 67.1±4.15, 24.7±5.5, and 1.7±0.2 respectively.

The overall mean renal length was 10.4cm, mean renal width 4.6cm, mean renal size 156.6cm$^3$, mean cortical thickness 7.5mm and mean parenchymal thickness 16.0mm.

Mean renal length for the right kidney was 10.1±0.8cm, width 4.1±0.6cm, depth 6.4±0.9, cortical thickness 7.2±2.7mm, and parenchymal thickness 15.2±3.6mm. Readings for the left kidney were 10.7±6.0cm, 4.7±0.8cm, 6.5±0.8 cm, 7.7±2.6mm and 16.8±4.1mm for mean length, width, depth, cortical thickness and parenchymal thickness respectively (Table 1).

Mean renal size (cm$^3$) 0.523 x length (cm) x width (cm) x depth (cm) on the right was 139±34.2cm$^3$ and 173.7±13.5cm$^3$ on the left. The measured renal dimensions among the subjects were higher on the left side than the right side. The differences observed was statistically significant ($p<0.05$, Table 1) for measured volume, width, cortical thickness and parenchymal thickness but not statistically significant ($p>0.05$, Table 1) for measured length and depth.

A total of one hundred and seventeen (117) representing 30.0% of the subjects scanned were within the 18-29 years age group while 13 of the subjects investigated were within the 60-69 years age group representing 3.3%. This distribution was statistically significant ($P<0.05$, Table 2). There was progressive increase in renal sizes with increasing age. Renal size increases from 18 years to 39 years and decline at 60 years of age. This relationship was statistically significant ($P<0.05$, Table 2). In each age group, there was a significant difference in renal sizes between the right and left kidney with the renal size on the left greater than right. This was statistically significant. ($P<0.05$, Table 2). Using the Pearson correlation, there was a positive correlation between age and renal size. ($P<0.05$, Pearson correlation = 0.25 for right kidney and $P<0.01$, Pearson correlation 0.32 for left kidney).

One hundred and ninety-seven (197) representing 50.5% of the subjects scanned were female while 193 representing 49.5% of subjects scanned were male. This distribution was not statistically significant ($P>0.05$, Table 3). In males the mean right renal length, width and depth were 10.2±0.8cm, 4.1±0.5cm and 6.4±0.9cm respectively and for the left 11.3±9.7cm, 4.1±0.5cm and 6.5±0.9cm respectively. In females mean right renal length, width and depth were 10.1±0.8cm, 4.1±0.5cm and 6.4±0.8cm respectively and for the left 10.3±0.9cm, 4.1±0.6cm and 6.6±0.8cm respectively. Mean right and left renal size was 140.2±33.7cm$^3$ and 183±48.9cm$^3$ respectively for males and 138.6±34.8cm$^3$ and 164.3±47.7cm$^3$ respectively for females. Males have larger renal size compare to females and measured left renal size was larger than the right in both. This association was not statistically significant ($P>0.05$, Table 3).

A total of one hundred and seventy-eight (178) representing 45.6% of the subjects scanned were within 25.0-29.9 BMI group while thirty-two of the subjects investigated were within less than 18.5 BMI group representing 8.2%. This distribution was statistically significant ($P<0.05$, Table 4). There was a progressive increase in renal sizes with increasing BMI. This relationship was statistically significant ($P<0.05$, Table 4). BMI has a positive correlation with renal sizes (Pearson correlation= 0.37 for right kidney and 0.52 for left kidney). Renal size correlated positively with BSA (Pearson correlation= 0.72 for right kidney and 0.90 for left kidney, Table 5).

DISCUSSION

The renal size of a population is a very useful diagnostic parameter in the practice of medicine. Since the renal size is affected by various factors, it is, therefore, necessary to first determine standardized values for normal renal dimensions as variability in the values of normal renal size depends on body size, age, gender, and ethnicity. Ultrasonography is one of the most common imaging methods used in routine practice for visualizing the normal anatomy of the kidneys also in disease conditions; this is so because it is safe, non-invasive, easy availability, reliable, repeatable and cost effective method as such ultrasound has been regarded as an imaging technique of choice in most of the clinical survey among all the other imaging modalities. In comparison with an intravenous pyelogram, ultrasound is more accurate and suffers neither from the geometric magnification of X-ray nor from a possible increase in kidney size by osmotic diuresis through iodinated contrast material (Brandt et
Table 1. Renal dimensions and side differences

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Right kidney</th>
<th>Left kidney</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (cm)</td>
<td>10.1±0.8</td>
<td>10.7±6.0</td>
<td>=0.45</td>
</tr>
<tr>
<td>Width (cm)</td>
<td>4.1±0.6</td>
<td>4.7±0.8</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>6.4±0.9</td>
<td>6.5±0.8</td>
<td>0.38</td>
</tr>
<tr>
<td>Volume (cm$^3$)</td>
<td>139.5±34.2</td>
<td>173.7±130.5</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Cortical (mm)</td>
<td>7.2±2.7</td>
<td>7.7±2.6</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Parenchyma (mm)</td>
<td>15.2±3.6</td>
<td>16.8±4.1</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

Table 2. Age distribution and mean renal dimensions

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>Frequency (%)</th>
<th>Mean Length (cm)</th>
<th>Mean Width (cm)</th>
<th>Mean Depth (cm)</th>
<th>Mean renal size (cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 – 29</td>
<td>117(30.0)</td>
<td>10.2±0.8</td>
<td>14.9±1.0</td>
<td>6.3±0.9</td>
<td>142.3±32.1</td>
</tr>
<tr>
<td>30 – 39</td>
<td>82(21.0)</td>
<td>10.4±0.7</td>
<td>15.2±0.9</td>
<td>6.4±0.9</td>
<td>144.3±37.9</td>
</tr>
<tr>
<td>40 – 49</td>
<td>90(23.1)</td>
<td>10.1±0.8</td>
<td>12.2±14.2</td>
<td>6.5±0.8</td>
<td>145.3±45.7</td>
</tr>
<tr>
<td>50 – 59</td>
<td>88(22.6)</td>
<td>10.1±0.7</td>
<td>10.3±1.1</td>
<td>6.5±0.8</td>
<td>136.4±34.3</td>
</tr>
<tr>
<td>60 – 69</td>
<td>13(3.3)</td>
<td>9.4±0.7</td>
<td>10.3±1.0</td>
<td>6.4±0.9</td>
<td>133.3±30.8</td>
</tr>
</tbody>
</table>

Table 3. Sex and mean renal dimensions

<table>
<thead>
<tr>
<th>Sex</th>
<th>Frequency (%)</th>
<th>Length (cm)</th>
<th>Width (cm)</th>
<th>Depth (cm)</th>
<th>renal size (cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>193 (49.5)</td>
<td>10.2±0.8</td>
<td>11.3±9.7</td>
<td>6.4±0.9</td>
<td>140.2±33.7</td>
</tr>
<tr>
<td>Female</td>
<td>197 (50.5)</td>
<td>10.1±0.8</td>
<td>4.1±0.6</td>
<td>10.3±0.9</td>
<td>138.6±34.7</td>
</tr>
</tbody>
</table>

Table 4. BMI and mean renal size

<table>
<thead>
<tr>
<th>BMI</th>
<th>Frequency (%)</th>
<th>Right (cm$^3$)</th>
<th>Left (cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;18.5</td>
<td>32 (8.2)</td>
<td>133.1</td>
<td>154.7</td>
</tr>
<tr>
<td>18.5-24.5</td>
<td>76 (19.5)</td>
<td>138.8</td>
<td>160.5</td>
</tr>
<tr>
<td>25.0-29.9</td>
<td>178 (45.6)</td>
<td>141.5</td>
<td>198.8</td>
</tr>
<tr>
<td>≥30</td>
<td>104 (26.7)</td>
<td>145.5</td>
<td>210.7</td>
</tr>
</tbody>
</table>

Table 5. Correlation of renal size with BMI and BSA

<table>
<thead>
<tr>
<th>Renal size</th>
<th>BMI</th>
<th>BSA</th>
<th>Correlation coefficient</th>
<th>P-value</th>
<th>Correlation coefficient</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>0.37</td>
<td>0.02</td>
<td>0.72</td>
<td>0.02</td>
<td>0.90</td>
<td>0.03</td>
</tr>
<tr>
<td>Left</td>
<td>0.52</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

al., 1982). Some studies have used CT (Gremigni et al., 1984) and MRI (Bakker et al., 1998) to determine normal kidney size. Although these methods show a better repeatability they are quite expensive in this environment and kidney size measurements on CT and MRI result in a 24% underestimation of the renal size (Bakker et al., 1998).

The size of the kidneys provides a rough indication of the renal function. Renal disease can increase or decrease renal size. Renal size and function decrease in chronic renal failure, renal artery stenosis on the other hand increases in early diabetic mellitus and renal inflammation. Standard parameters used in routine ultrasound scans of the kidneys are renal length, renal width, depth and renal parenchymal thickness. Additional measurement acquired using these parameters include renal volume. However renal size estimation can be performed measuring renal length, renal volume, cortical thickness although the most accurate of these parameters is renal volume (Kang et al., 2007; Emamian et al., 1995) as the shape of kidney varies considerably. The renal length and volume measurements are used frequently to determine the renal size and serve as the basis for making clinical
decisions since both serve as surrogates for renal functional reserve though renal volume correlated better with renal mass (Kang et al., 2007; Widjaja et al., 2004). In autopsy studies, kidney volume has been shown to correlate well, although indirectly, with the number of functioning nephrons (Widjaja et al., 2004). However renal length measurement is preferred to renal volume estimation clinically because of lower observer variation; more over it is reliable, simple, practical, reproducible measurement of renal size (Emamian et al., 1995; Raza et al., 2011).

In this study, the left kidney was larger than the right in all renal dimensions regarding age and sex. This was consistent with other studies (Buchholz et al., 2000; Okoye et al., 2005; Emamian et al., 1993; Raza et al., 2011; Sadisu et al., 2015). According to most literature, there are differences between the right and left renal size with the left renal size larger than the right. This may be due to liver on the right which does not allow comparable growth of the right kidney to that which is attained by the left kidney because there is less space for growth on the right. Furthermore, the left renal artery is shorter and straighter than the right; the increased blood flow in the left renal artery may result in relatively increased in volume (Emamian et al., 1993; Ameer et al., 1999).

The right and left mean renal size was 139±34.2cm³ and 173.7±13.5cm³ respectively with left kidney larger than the right. This was statistically significant (p<0.001). These values were higher than values obtained in Denmark (Arooj et al., 2011); (Right kidney=146cm³; Left kidney=119.7cm³), northwest Nigeria (Sadisu et al., 2015); (Right kidney=109.6 cm³, Left kidney=119.7cm³) and Pakistan (Buchholz et al., 2000), (Right kidney =70 cm³, Left kidney=82cm³). This difference shows that renal sizes are different among different races and that we cannot use the same nomogram for different ethnicities from the same country. This further affirmed the fact that normal values for each region should be estimated. The larger values in this study compared to other studies (Buchholz et al., 2000, Sadisu et al., 2015) could be as result of the method used in generating the renal sizes. Other studies (Buchholz et al., 2000, Sadisu et al., 2015) arrived at renal size estimation using length, width and cortical thickness. The differences in these values could be as a result of environmental, genetic and nutritional factors. The overall mean renal length in this study was lower than values in the North-West Nigeria (Sadisu et al., 2015 ) (right kidney=11.3cm; left kidney=11.6cm), but similar to what was obtained in the southeast Nigeria (Okoye et al., 2005 (right kidney=10.33cm; left kidney=10.6cm) and larger than values in Jamaican (Barton et al., 2000) (right kidney=9.7cm; left kidney=10cm). The above reasons could be responsible for these differences in renal length.

Age is important because it alters both anatomy and physiology of the human body and has an important bearing on renal size, as renal size is said to decrease with aging. In children, there is a close relationship between linear growth and kidney length (Ameer et al., 1999) which indicate 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 (Raza et al., 2011). It is well established that by 70 years, as much as 30 -50% of cortical glomeruli atrophy; manifested by a progressive loss of renal mass (Melk and Halloran 2001). In this study renal size increased in 18-29 and 20-39 years age groups, relatively more or less stable in 40-49 and 50-59 age groups and begins to decline in age group 60-69. Similar finding was obtained in a study by (Buchholz et al., 2000). From the 5th decade on, decrease in renal size is approximately 0.5cm per decade, especially due to a reduction of about 1% per year in blood flow after the third decade (McLachlan and Wasserman 1981). This may be responsible for the progressive decrease in renal size from middle age. Other factors implicated in decrease of renal volume with aging include glomerulonephrosis, tubulointerstitial fibrosis (Sandep et al., 2013).

The right and left renal sizes of males were compared to the right and left renal size of the females. Left and right renal size and was larger in males than the in females. This was not statistically significant. This finding was consistent with other studies (Okoye et al., 2005; Wang et al., 1989; Sadisu et al., 2015) but contrary to study in Pakistan (Buchholz et al., 2000). Gender differences in renal size can be accounted for by the disparity in body sizes as height and weight were independent predictors of renal size.

This study showed a positive correlation between renal size with BMI and BSA. For each BMI grouping, there is a corresponding increase in renal size. This was obtained in other studies (Buchholz et al., 2000; Emamian et al., 1993; Raza et al., 2011). This is most likely due to the fact that the kidneys develop at the same rate as the whole body develops. Others studies have also shown a correlation between renal volume with height and weight (Wang et al., 1989; Raza et al., 2011). (Zeb et al., 2012) indicating that body habitus and built is a major predictor of renal size in healthy adults; some parameters may have greater impact than others, but it is the amalgam of these anthropometric measurements which determines kidney size in healthy individual.

**CONCLUSION**

In conclusion, we have established normal renal dimension for the adult population in Abuja north central Nigeria. This study also showed that renal size was larger on the left, in males, increasing with BMI, and
begins to decreases after age 60 years. Positive correlation was established between renal size and age, side, BMI and BSA. Body habitus, age, sex, and side should be considered so as to differentiate between pathological and non-pathological small or large renal sizes.

REFERENCES


