NORMAL VARIANCE IN ULTRASOUND MEASURED RENAL DIMENSIONS WITH AGE, SEX AND BODY HABITUS IN A SPECIFIC POPULATION WITHOUT KNOWN RENAL DISEASE

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ABSTRACT

Introduction: Evaluation and follow-up of patients with renal diseases is commonly done by renal ultrasonography. Renal size is influenced by some factors such as age, height, weight, body mass index and ethnicity. The aim of this study was to evaluate the normal range of dimensions of kidney, like length, width, thickness & volume and its correlation with age, sex, height, weight and body mass index in population of eastern Odisha by Ultrasonography.

Material & Methods: Ultrasound was performed on 223 subjects. Initially the image was taken in supine and later in both lateral decubitus position. The measurements of kidney were taken from the freezed images in longitudinal axis and the transverse section obtained at the level of the renal hilum.

Results: In 63.68% cases the kidney length and in 81.17% cases, the kidney volume was larger on left side. A decline trend in all the measurements of parameters beyond 50 years was observed in the present study. However, the mean volume on both sides had a slight increasing trend in 61-70 years age group.

Keywords: Renal Ultrasonography, renal size, body mass index, kidney volume,

INTRODUCTION

The kidneys, one of the essential organs of body are part of the urinary system. It excrete the metabolic waste by filtering the plasma of the blood [1]. Renal function has close relation with renal size. Nephrological disorders like renal infections, inflammation and co-morbid conditions like hypertension and diabetes mellitus affect the renal size [2-5]. Chronic kidney diseases, renal growth, cysts can be associated with change in size and shape of kidney. Thus, it is imperative to establish the pattern of normal renal dimensions. Kidney volume is regarded as the most precise indicator of kidney size, which correlates best with the subject's height, weight and total body area [6,7]. Renal ultrasonography is currently used for the evaluation and follow-up of patients with renal diseases, which is a relatively inexpensive, quick, non-invasive and radiation-free imaging modality. Renal size is influenced by some factors such as age, gender, height, weight and ethnicity [8]. Renal length is most commonly used for quantitative measure of renal size for comparison with established standards [9]. The present study was conducted in the Department of Anatomy, Kalinga Institute of Medical Sciences, Bhubaneswar, Odisha, India from October 2011 to August 2013 after the approval from the ethical committee. It was conducted in collaboration with the Department of Radiodiagnosis. The aim of this study was to evaluate the normal range of dimensions of kidney and its correlation with age, sex, height, weight and body mass index in population of eastern Odisha in different age groups by ultrasonography.

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MATERIAL AND METHODS

Real time sonography was performed on 223 subjects and all measurements were taken by the same observer. Subjects having chronic hypertensive disease, diabetes mellitus, tuberculosis, malignancy of anywhere in body, chronic kidney disease, single or multiple renal cysts, unilateral kidney, malignancy of kidney and previous renal surgery were excluded from the study.

Initially the image was taken in supine and later in both lateral decubitus position. The measurements of kidney were taken from the freezeed images in longitudinal axis and the transverse section obtained at the level of the renal hilum (Fig. 1).

Fig. 1: Renal measurements at sonography

A standardized weighing machine was used to record the weight and an infant weighing scale for infants. Measurement of the standing height was taken by the measuring scale fixed to the wall. The supine lengths were measured on an infanto-meter in children below 2 years. Height was measured and rounded to the nearest 0.5 cm. Body Mass Index (BMI) was calculated as:

\[
\text{BMI (kg/m}^2\text{)} = \text{weight (kg)} / [\text{height (m)}]^2
\]

Parameters for Measurement of Kidney

Length: Maximum longitudinal kidney length measured in a sagittal plane by placing the electronic calipers on the outer edges of the caudal and cranial side.

Thickness: Maximum Antero-Posterior diameters of the Transverse Section.

Width (Breadth): Maximum distance between lateral and medial border of the transverse section.

Volume: The renal volume (cm³) was calculated from length, breadth & thickness by ellipsoid formula as \(0.523 \times \text{Length (in cm)} \times \text{Width (in cm)} \times \text{Thickness (in cm)}\).

Ethics statement

The study protocol was approved by the ethics committee KIIT university, Bhubaneswar (Ref: KIIT-U/Exam/Evaluation/5752/11, Date11/11/2011). Written informed consent was obtained from all subjects.

RESULTS

Data analysis was done by using software SPSS 13 version. Table 1 presents age and sex wise distribution of subjects at interval of 10 years. The analysis of the parameters by ten years age group was done through an ANOVA and presented in Table 2 for right kidney. The mean length of right kidney was \(94.4 \pm 11.8\) mm, the mean breadth was \(41.2 \pm 8\) mm, the mean thickness was \(46.2 \pm 9.5\) mm and the mean volume was \(98.3 \pm 38.2\) cm³ and significant statistically (\(p = 0.000\)). The mean right renal length, breadth, thickness and volume increased with age upto 50 years and after that there was a decline trend. The mean volume of right kidney showed slight increase trend between 61-70 years (Table 2, Fig. 2).
Ultrasound measured renal dimensions......

### Table 1: Age and sex wise distribution of subjects

| Age Group (Years) | Total Number | Sex | Number | % | Number | % |
|-------------------|--------------|-----|--------|---|--------|---|
|                   |              | Male |        |   | Female |   |
|                   |              | Number | %     |   | Number | %  |
| ≤10               | 26           | 15   | 57.7   | 11| 42.3   |   |
| 11 - 20           | 42           | 24   | 57.1   | 18| 42.9   |   |
| 21 - 30           | 48           | 18   | 37.5   | 30| 62.5   |   |
| 31 - 40           | 42           | 21   | 50.0   | 21| 50.0   |   |
| 41 - 50           | 28           | 14   | 50.0   | 14| 50.0   |   |
| 51 - 60           | 18           | 4    | 22.2   | 14| 77.8   |   |
| 61 - 70           | 19           | 9    | 47.4   | 10| 52.6   |   |
| Total             | 223          | 105  | 47.1   | 118| 52.9   |   |

### Table 2: Right renal dimensions distributed by age (grouped by decade of life)

| Parameters | Age Group (Years) | N  | Mean   | Std. Deviation | 95% Confidence Interval for Mean | Minimum | Maximum | f & p Value |
|------------|-------------------|----|--------|----------------|----------------------------------|---------|---------|-------------|
|            |                   |    |        |                | Lower Bound                      | Upper Bound |        |
| Length     | ≤10               | 26 | 75.208 | 11.679         | 70.491                          | 79.925 | 55.3 | 97.7 | 21.270 |
| Right      | 11 - 20           | 42 | 94.048 | 9.250          | 91.165                          | 96.930 | 72.7 | 109.4 | 0.000 |
| Kidney     | 21 - 30           | 48 | 98.152 | 9.201          | 95.480                          | 100.824 | 80.4 | 119.5 | 0.000 |
|            | 31 - 40           | 42 | 97.926 | 10.167         | 94.758                          | 101.094 | 78.7 | 120.1 | 0.000 |
|            | 41- 50            | 28 | 99.043 | 8.600          | 95.708                          | 102.378 | 84.4 | 122.7 | 0.000 |
|            | 51 - 60           | 18 | 96.439 | 6.333          | 93.290                          | 99.588  | 80.7 | 110.5 | 0.000 |
|            | 61 - 70           | 19 | 95.542 | 9.493          | 90.967                          | 100.117 | 78.9 | 113.5 | 0.000 |
| Total      | 223               |    | 94.413 | 11.801         | 92.855                          | 95.970  | 55.3 | 122.7 | 14.527 |
| Breadth    | ≤10               | 26 | 30.462 | 5.182          | 28.369                          | 32.555 | 21.9 | 43.1 | 0.000 |
| Right      | 11 - 20           | 42 | 40.050 | 6.522          | 38.017                          | 42.083 | 29.8 | 53.4 | 14.527 |
| Kidney     | 21 - 30           | 48 | 44.677 | 8.739          | 42.140                          | 47.215 | 31.3 | 63.9 | 0.000 |
|            | 31 - 40           | 42 | 44.136 | 6.518          | 42.105                          | 46.167 | 34.1 | 62.1 | 0.000 |
|            | 41- 50            | 28 | 41.882 | 7.071          | 39.140                          | 44.624 | 32.1 | 57.6 | 0.000 |
|            | 51 - 60           | 18 | 40.961 | 4.808          | 38.570                          | 43.352 | 34.6 | 52.9 | 0.000 |
|            | 61 - 70           | 19 | 42.858 | 5.663          | 40.129                          | 45.587 | 32.9 | 50.3 | 0.000 |
| Total      | 223               |    | 41.240 | 7.978          | 40.188                          | 42.293 | 21.9 | 63.9 | 0.000 |
The mean left renal length was 97.4 ± 12mm, the mean breadth was 46.4 ± 7.6 mm, the mean thickness was 47.5 ± 8.2 mm & the mean volume was 115.8 ± 41.1 cm³ and correlated statistically significant (p = 0.000). The mean length, breadth & volume increased up to 41-50 years age group and in thickness the increase was up to 51-60 years age group, after that there was a declining trend up to 70 years (Table 3, Fig. 3).

Table 3: Left renal dimensions distributed by age (grouped by decade of life)
### Ultrasound measured renal dimensions

**Breadth Left Kidney (mm)**

| Age Group | Count | Mean ± SD | 95% CI | N | Mean ± SD | 95% CI |
|-----------|-------|-----------|--------|---|-----------|--------|
| ≤10       | 26    | 35.565 ± 6.787 | 32.824 ± 38.307 | 25.8 | 49.5 |
| 11 - 20   | 42    | 45.388 ± 7.678 | 42.996 ± 47.781 | 30 | 58.7 |
| 21 - 30   | 48    | 49.152 ± 5.798 | 47.468 ± 50.836 | 39.4 | 61.6 |
| 31 - 40   | 42    | 48.688 ± 6.968 | 46.517 ± 50.859 | 38.5 | 69.1 |
| 41 - 50   | 28    | 48.654 ± 5.444 | 46.543 ± 50.764 | 35.5 | 60.7 |
| 51 - 60   | 18    | 46.356 ± 5.333 | 43.703 ± 49.008 | 38.4 | 56.5 |
| 61 - 70   | 19    | 48.074 ± 5.118 | 45.607 ± 50.540 | 37.6 | 55.7 |
| Total     | 223   | 46.391 ± 7.584 | 45.391 ± 47.392 | 25.8 | 69.1 |

**Thickness Left Kidney (mm)**

| Age Group | Count | Mean ± SD | 95% CI | N | Mean ± SD | 95% CI |
|-----------|-------|-----------|--------|---|-----------|--------|
| ≤10       | 26    | 36.027 ± 6.660 | 33.337 ± 38.717 | 24.2 | 48.4 |
| 11 - 20   | 42    | 46.348 ± 7.686 | 43.953 ± 48.743 | 34.9 | 66.9 |
| 21 - 30   | 48    | 51.260 ± 7.304 | 49.140 ± 53.381 | 38.2 | 73 |
| 31 - 40   | 42    | 49.593 ± 6.154 | 47.675 ± 51.511 | 33.1 | 67 |
| 41 - 50   | 28    | 48.868 ± 6.043 | 46.524 ± 51.211 | 39.5 | 61 |
| 51 - 60   | 18    | 49.722 ± 8.171 | 45.659 ± 53.785 | 40.8 | 64.4 |
| 61 - 70   | 19    | 47.837 ± 6.838 | 44.541 ± 51.133 | 37.4 | 62 |
| Total     | 223   | 47.529 ± 8.230 | 46.443 ± 48.615 | 24.2 | 73 |

**Volume Left Kidney (cm³)**

| Age Group | Count | Mean ± SD | 95% CI | N | Mean ± SD | 95% CI |
|-----------|-------|-----------|--------|---|-----------|--------|
| ≤10       | 26    | 53.377 ± 6.660 | 44.393 ± 62.360 | 20.9 | 97.1 |
| 11 - 20   | 42    | 109.196 ± 38.288 | 97.265 ± 121.127 | 48.2 | 205.8 |
| 21 - 30   | 48    | 134.885 ± 35.387 | 124.610 ± 145.161 | 77.9 | 232.4 |
| 31 - 40   | 42    | 129.747 ± 34.825 | 118.895 ± 140.599 | 54 | 219 |
| 41 - 50   | 28    | 128.268 ± 28.100 | 117.372 ± 139.164 | 87.8 | 211 |
| 51 - 60   | 18    | 115.578 ± 39.414 | 95.978 ± 135.178 | 11.6 | 182.3 |
| 61 - 70   | 19    | 118.968 ± 26.991 | 105.959 ± 131.978 | 81.2 | 165.8 |
| Total     | 223   | 115.830 ± 41.113 | 110.405 ± 121.256 | 11.6 | 232.4 |

**Fig. 2:** Parameters of right kidney by age

A - Length of kidney  
B - Breadth of kidney  
C - Thickness of kidney  
D - Volume of kidney

**Fig. 3:** Parameters of left kidney by age

A - Length of kidney  
B - Breadth of kidney  
C - Thickness of kidney  
D - Volume of kidney
Ultrasound measured renal dimensions......

The mean values of parameters of right and left kidneys were analysed respectively by sex along with significant values of ‘t’ test (Table 4 & 5). It was found that all the parameters of male kidney were larger than female kidney on both sides (Fig. 4 & 5) and significant statistically except the length.

Table 4: Comparison of parameters of right kidney by sex

| Group Statistics                  | Sex     | N   | Mean   | Std. Deviation | Std. Error Mean | 95% Confidence Interval for Mean | t Value | p Value |
|----------------------------------|---------|-----|--------|----------------|-----------------|---------------------------------|---------|---------|
| Length Right Kidney (mm)         | Male    | 105 | 94.866 | 13.777         | 1.345           | 92.230 - 97.501                 | 0.530   | 0.597   |
|                                  | Female  | 118 | 94.009 | 9.757          | 0.898           | 92.249 - 95.770                 | 0.530   | 0.597   |
| Breadth Right Kidney (mm)        | Male    | 105 | 42.624 | 8.821          | 0.861           | 40.937 - 44.311                 | 2.437   | 0.016   |
|                                  | Female  | 118 | 40.009 | 6.953          | 0.640           | 38.755 - 41.264                 | 2.437   | 0.016   |
| Thickness Right Kidney (mm)      | Male    | 105 | 47.540 | 9.538          | 0.931           | 45.716 - 49.364                 | 1.964   | 0.051   |
|                                  | Female  | 118 | 45.047 | 9.375          | 0.863           | 43.356 - 46.739                 | 1.964   | 0.051   |
| Volume Right Kidney (cm³)        | Male    | 105 | 106.66 | 43.842         | 4.279           | 98.278 - 115.050                | 3.069   | 0.002   |
|                                  | Female  | 118 | 90.940 | 30.626         | 2.819           | 85.414 - 96.466                 | 3.069   | 0.002   |

Table 5: Comparison of parameters of left kidney by sex

| Group Statistics                  | Sex     | N   | Mean   | Std. Deviation | Std. Error Mean | 95% Confidence Interval for Mean | t Value | p Value |
|----------------------------------|---------|-----|--------|----------------|-----------------|---------------------------------|---------|---------|
| Length Left Kidney (mm)          | Male    | 105 | 98.181 | 14.052         | 1.371           | 95.493 - 100.869                | 0.950   | 0.343   |
|                                  | Female  | 118 | 96.611 | 10.026         | 0.923           | 94.802 - 98.420                 | 0.950   | 0.343   |
| Breadth Left Kidney (mm)         | Male    | 105 | 47.437 | 8.699          | 0.849           | 45.773 - 49.101                 | 1.920   | 0.056   |
|                                  | Female  | 118 | 45.461 | 6.325          | 0.582           | 44.320 - 46.602                 | 1.920   | 0.056   |
| Thickness Left Kidney (mm)       | Male    | 105 | 49.146 | 8.762          | 0.855           | 47.470 - 50.822                 | 2.784   | 0.006   |
|                                  | Female  | 118 | 46.090 | 7.474          | 0.688           | 44.741 - 47.438                 | 2.784   | 0.006   |
| Volume Left Kidney (cm³)         | Male    | 105 | 124.534| 46.865         | 4.574           | 115.57 - 133.498                | 2.980   | 0.003   |
|                                  | Female  | 118 | 108.086| 33.562         | 3.090           | 102.03 - 114.142                | 2.980   | 0.003   |
Ultrasound measured renal dimensions......

Fig. 4: Parameters of right kidney by sex

Fig. 5: Parameters of left kidney by sex

The mean parameters of kidney by different weight groups for right and left kidneys respectively were analysed which revealed that as the weight increases the parameters of kidney also increases and significant statistically (p = 0.000) (Table 6 & 7, Fig. 6 & 7).

Table 6: Relationship between right renal dimensions and individual’s weight (kg)

| Parameters       | Weight Groups | Mean   | Std. Deviation | 95% Confidence Interval for Mean | f value | p value |
|------------------|---------------|--------|----------------|---------------------------------|---------|---------|
| Length Right Kidney (mm) | ≤30           | 75.663 | 11.186         | 71.486 - 79.840                 | 47.462  | 0.000   |
|                  | 31 - 40       | 89.944 | 7.878          | 86.828 - 93.061                 |         |         |
|                  | 41 - 50       | 95.732 | 5.683          | 94.063 - 97.401                 |         |         |
|                  | 51 - 60       | 96.401 | 5.683          | 94.063 - 97.401                 |         |         |
|                  | 61 - 70       | 103.021| 7.304          | 100.472 - 105.569               |         |         |
|                  | >70           | 105.776| 8.909          | 101.196 - 110.357               |         |         |
|                  | Total         | 94.413 | 11.801         | 92.855 - 95.970                 |         |         |

| Breadth Right Kidney (mm) | ≤30           | 30.710 | 4.866          | 28.893 - 32.527                 | 33.340  | 0.000   |
|                           | 31 - 40       | 38.522 | 5.640          | 36.291 - 40.753                 |         |         |
|                           | 41 - 50       | 40.462 | 5.407          | 38.874 - 42.049                 |         |         |
|                           | 51 - 60       | 42.250 | 6.192          | 40.751 - 43.749                 |         |         |
|                           | 61 - 70       | 47.906 | 7.552          | 45.271 - 50.541                 |         |         |
|                           | >70           | 48.924 | 6.524          | 45.569 - 52.278                 |         |         |
|                           | Total         | 41.240 | 7.978          | 39.188 - 42.293                 |         |         |

| Thickness Right         | ≤30           | 36.193 | 6.235          | 33.865 - 38.522                 | 16.646  | 0.000   |
|                         | 31 - 40       | 43.974 | 8.549          | 40.592 - 47.356                 |         |         |
### Table 7: Relationship between left renal dimensions and individual’s weight (kg)

| Parameters          | Weight Groups | Mean   | Std. Deviation | 95% Confidence Interval for Mean | f value | p value |
|---------------------|---------------|--------|----------------|---------------------------------|---------|---------|
|                     |               |        |                | Lower Bound | Upper Bound |         |         |
| Kidney (mm)         |               |        |                |              |            |         |         |
| 41 - 50             | 43.660        | 7.540  |               | 41.446      | 45.874     |         |         |
| 51 - 60             | 49.518        | 7.946  |               | 47.594      | 51.441     |         |         |
| 61 - 70             | 52.085        | 10.927 |               | 48.273      | 55.898     |         |         |
| >70                 | 49.653        | 6.654  |               | 46.232      | 53.074     |         |         |
| Total               | 46.221        | 9.513  |               | 44.966      | 47.477     |         |         |
| Volume Right Kidney | ≤30           | 45.426 | 16.673         | 39.201      | 51.652     | 44.192  | 0.000   |
| (cm³)               | 31 - 40       | 81.041 | 22.883         | 71.988      | 90.093     |         |         |
| 41 - 50             | 90.480        | 22.108 |               | 83.989      | 96.971     |         |         |
| 51 - 60             | 107.858       | 29.862 |               | 100.629     | 115.086    |         |         |
| 61 - 70             | 132.432       | 33.838 |               | 120.625     | 144.239    |         |         |
| >70                 | 134.718       | 34.035 |               | 117.219     | 152.217    |         |         |
| Total               | 98.344        | 38.166 |               | 93.307      | 103.380    |         |         |
| Length Left Kidney  | ≤30           | 77.883 | 10.458         | 73.978      | 81.788     | 42.406  | 0.000   |
| (mm)                | 31 - 40       | 95.552 | 8.187          | 92.313      | 98.790     |         |         |
| 41 - 50             | 97.557        | 8.448  |               | 95.077      | 100.038    |         |         |
| 51 - 60             | 99.919        | 8.358  |               | 97.896      | 101.942    |         |         |
| 61 - 70             | 104.794       | 7.791  |               | 102.076     | 107.513    |         |         |
| >70                 | 108.824       | 9.759  |               | 103.806     | 113.841    |         |         |
| Total               | 97.350        | 12.087 |               | 95.755      | 98.945     |         |         |
| Breadth Left Kidney | ≤30           | 36.583 | 7.089          | 33.936      | 39.230     | 25.788  | 0.000   |
| (mm)                | 31 - 40       | 43.496 | 7.332          | 40.596      | 46.397     |         |         |
| 41 - 50             | 45.906        | 4.528  |               | 44.577      | 47.236     |         |         |
| 51 - 60             | 48.400        | 6.203  |               | 46.898      | 49.902     |         |         |
| 61 - 70             | 50.765        | 6.347  |               | 48.550      | 52.979     |         |         |
| >70                 | 52.859        | 4.351  |               | 50.622      | 55.096     |         |         |
Ultrasound measured renal dimensions......

| Parameters          | Weight Groups | Mean   | Std. Deviation | 95% Confidence Interval for Mean | f value | p value |
|---------------------|---------------|--------|----------------|---------------------------------|---------|---------|
|                     |               |        |                | Lower Bound | Upper Bound                     |         |         |
| Parameters          |               |        |                |               |         |         |
|                     |               |        |                |               |         |         |
|                     |               |        |                |               |         |         |
| Thickness Left Kidney (mm) | ≤30       | 36.603 | 6.444          | 34.197 | 39.009 |         |         |         |
|                     | 31 - 40       | 45.922 | 6.915          | 43.187 | 48.658 |         |         |         |
|                     | 41 - 50       | 47.100 | 6.608          | 45.160 | 49.040 | 22.226 | 0.000   |         |
|                     | 51 - 60       | 50.087 | 6.516          | 48.509 | 51.664 |         |         |         |
|                     | 61 - 70       | 52.574 | 7.525          | 49.948 | 55.199 |         |         |         |
|                     | >70           | 50.224 | 6.961          | 46.644 | 53.803 |         |         |         |
|                     | Total         | 47.529 | 8.230          | 46.443 | 48.615 |         |         |         |
| Volume Left Kidney (cm³) | ≤30       | 56.820 | 23.353         | 48.099 | 65.540 |         |         |         |
|                     | 31 - 40       | 101.623| 29.259         | 90.049 | 113.198|         |         |         |
|                     | 41 - 50       | 111.474| 27.596         | 103.372| 119.576| 37.387 | 0.000   |         |
|                     | 51 - 60       | 125.658| 34.518         | 117.303| 134.013|         |         |         |
|                     | 61 - 70       | 147.419| 32.892         | 135.942| 158.895|         |         |         |
|                     | >70           | 152.088| 28.449         | 137.461| 166.715|         |         |         |
|                     | Total         | 115.830| 41.113         | 110.405| 121.256|         |         |         |

Fig. 6: Parameters of right kidney by weight
Fig. 7: Parameters of left kidney by weight
A-Length of kidney B- Breadth of kidney C-Thickness of kidney D- Volume of kidney

The mean of parameters of right and left kidney along with ANOVA results according to height was analysed (Table 8 & 9, Fig. 8 & 9) and it was seen that there was an increasing trend of the magnitude of parameters with height, which was statistically significant (p = 0.000).
### Table 8. Relationship between right renal dimensions and individual’s height (cm)

| Parameters                  | Height Groups | Mean  | Std. Deviation | 95% Confidence Interval for Mean | f & p Value |
|-----------------------------|---------------|-------|----------------|---------------------------------|-------------|
|                             |               |       |                | Lower Bound | Upper Bound |               |             |
| Length Right Kidney (mm)    | ≤130          | 75.104| 11.558         | 70.333    | 79.875    | 48.671        |
|                             | 131 - 150     | 93.917| 8.609          | 91.521    | 96.314    |               |             |
|                             | 151 - 170     | 96.743| 9.195          | 95.108    | 98.377    |               |             |
|                             | >170          | 105.076| 7.479         | 101.672   | 108.481   |               |             |
|                             | Total         | 94.432| 11.824         | 92.868    | 95.996    | 0.000         |
| Breadth Right Kidney (mm)   | ≤130          | 30.620| 5.388          | 28.396    | 32.844    | 37.723        |
|                             | 131 - 150     | 38.390| 5.897          | 36.749    | 40.032    |               |             |
|                             | 151 - 170     | 43.476| 6.777          | 42.271    | 44.680    |               |             |
|                             | >170          | 47.990| 7.626          | 44.519    | 51.462    |               |             |
|                             | Total         | 41.264| 7.988          | 40.207    | 42.320    | 0.000         |
| Thickness Right Kidney (mm) | ≤130          | 35.408| 6.113          | 32.885    | 37.931    | 17.003        |
|                             | 131 - 150     | 45.398| 8.242          | 43.104    | 47.693    |               |             |
|                             | 151 - 170     | 48.002| 9.251          | 46.357    | 49.646    |               |             |
|                             | >170          | 50.867| 8.280          | 47.098    | 54.636    |               |             |
|                             | Total         | 46.245| 9.528          | 44.984    | 47.505    | 0.000         |
| Volume Right Kidney (cm³)   | ≤130          | 44.148| 17.254         | 37.025    | 51.270    | 42.534        |
|                             | 131 - 150     | 88.606| 25.839         | 81.412    | 95.799    |               |             |
|                             | 151 - 170     | 107.030| 33.181      | 101.132   | 112.928   |               |             |
|                             | >170          | 137.010| 36.658       | 120.323   | 153.696   |               |             |
|                             | Total         | 98.469| 38.206         | 93.416    | 103.523   | 0.000         |

### Table 9. Relationship between left renal dimensions and individual’s height (cm)

| Parameters                  | Height Groups | Mean  | Std. Deviation | 95% Confidence Interval for Mean | f & p Value |
|-----------------------------|---------------|-------|----------------|---------------------------------|-------------|
|                             |               |       |                | Lower Bound | Upper Bound |               |             |
| Length Left Kidney (mm)     | ≤130          | 76.120| 9.718          | 72.109     | 80.131     | 55.924        |
|                             | 131 - 150     | 96.729| 8.665          | 94.316     | 99.141     |               |             |
|                             | 151 - 170     | 100.406| 8.957        | 98.813     | 101.998    |               |             |
|                             | >170          | 106.233| 10.863       | 101.289    | 111.178    | 0.000         |
Ultrasound measured renal dimensions......

| Parameters                        | Height Groups | Mean     | Std. Deviation | 95% Confidence Interval for Mean | f & p Value |
|-----------------------------------|---------------|----------|----------------|---------------------------------|-------------|
|                                   |               |          |                | Lower Bound                     | Upper Bound |
| Total                             |               | 97.361   | 12.113         | 95.759                          | 98.963      |
| **Breadth Left Kidney (mm)**      | ≤130          | 35.612   | 6.338          | 32.996                          | 38.228      |
|                                  | 131 - 150     | 45.656   | 5.952          | 43.999                          | 47.313      |
|                                  | 151 - 170     | 48.360   | 6.450          | 47.213                          | 49.506      |
|                                  | >170          | 49.871   | 7.499          | 46.458                          | 53.285      |
| Total                             |               | 46.434   | 7.574          | 45.432                          | 47.436      |
| **Thickness Left Kidney (mm)**    | ≤130          | 35.924   | 6.759          | 33.134                          | 38.714      |
|                                  | 131 - 150     | 46.227   | 6.687          | 44.365                          | 48.089      |
|                                  | 151 - 170     | 50.048   | 7.080          | 48.790                          | 51.307      |
|                                  | >170          | 50.000   | 7.354          | 46.652                          | 53.348      |
| Total                             |               | 47.558   | 8.237          | 46.469                          | 48.648      |
| **Volume Left Kidney (cm³)**      | ≤130          | 52.916   | 21.566         | 44.014                          | 61.818      |
|                                  | 131 - 150     | 109.231  | 30.589         | 100.715                         | 117.748     |
|                                  | 151 - 170     | 127.686  | 35.739         | 121.333                         | 134.039     |
|                                  | >170          | 138.910  | 37.358         | 121.904                         | 155.915     |
| Total                             |               | 116.005  | 41.123         | 110.566                         | 121.444     |

The ANOVA results of the variation of parameters of kidney with the BMI, are represented in Table 10 and Fig. 10 for right kidney parameters and in Table 11 and Fig. 11 for left kidney parameters. The mean length, thickness, breadth and volume showed strong correlation with all the BMI groups and statistically significant (p = 0.000).
Table 10. Relationship between right renal dimensions and individual’s BMI (kg/m²)

| Parameters | BMI Groups | Mean | Std. Deviation | 95% Confidence Interval for Mean | f value | p value |
|------------|------------|------|----------------|-------------------------------|---------|---------|
|            |            |      |                | Lower Bound | Upper Bound |       |        |
| Length     | ≤ 15       | 77.921 | 10.144          | 73.988 | 81.855 | 18.280 | 0.000  |
| Right      | >15 & ≤ 17 | 88.927 | 11.354          | 84.341 | 93.513 |         |        |
| Kidney (mm)| >17 & ≤ 19 | 95.104 | 10.223          | 90.788 | 99.421 |         |        |
|           | >19 & ≤ 21 | 95.474 | 9.648           | 92.302 | 98.645 |         |        |
|           | >21 & ≤ 23 | 99.191 | 8.390           | 96.216 | 102.166 |         |        |
|           | >23 & ≤ 25 | 97.871 | 9.327           | 94.616 | 101.125 |         |        |
|           | >25 & ≤ 27 | 100.121 | 7.629          | 96.899 | 103.342 |         |        |
|           | >27        | 102.863 | 8.454          | 98.358 | 107.367 |         |        |
| Breadth    | ≤ 15       | 32.118 | 4.518           | 30.366 | 33.870 | 12.319 | 0.000  |
| Right      | >15 & ≤ 17 | 37.831 | 6.846           | 35.065 | 40.596 |         |        |
| Kidney (mm)| >17 & ≤ 19 | 40.942 | 5.709           | 38.531 | 43.352 |         |        |
|           | >19 & ≤ 21 | 40.603 | 7.227           | 38.227 | 42.978 |         |        |
|           | >21 & ≤ 23 | 43.730 | 8.186           | 40.828 | 46.633 |         |        |
|           | >23 & ≤ 25 | 44.812 | 5.537           | 42.880 | 46.744 |         |        |
|           | >25 & ≤ 27 | 44.996 | 8.640           | 41.348 | 48.644 |         |        |
|           | >27        | 46.350 | 7.329           | 42.444 | 50.256 |         |        |
| Thickness  | ≤ 15       | 39.854 | 7.988           | 36.756 | 42.951 | 6.921  | 0.000  |
| Right      | >15 & ≤ 17 | 41.231 | 7.856           | 38.058 | 44.404 |         |        |
| Kidney (mm)| >17 & ≤ 19 | 43.292 | 8.589           | 39.665 | 46.918 |         |        |
|           | >19 & ≤ 21 | 46.184 | 9.350           | 43.111 | 49.258 |         |        |
|           | >21 & ≤ 23 | 48.152 | 9.814           | 44.672 | 51.631 |         |        |
|           | >23 & ≤ 25 | 52.353 | 8.980           | 49.220 | 55.486 |         |        |
|           | >25 & ≤ 27 | 48.404 | 8.477           | 44.825 | 51.984 |         |        |
|           | >27        | 49.669 | 7.317           | 45.770 | 53.568 |         |        |
| Volume     | ≤ 15       | 53.443 | 19.847          | 45.747 | 61.138 | 15.825 | 0.000  |
| Right      | >15 & ≤ 17 | 75.332 | 28.459          | 63.837 | 86.826 |         |        |
| Kidney (cm³)| >17 & ≤ 19 | 91.492 | 27.131          | 80.035 | 102.948 |         |        |
|           | >19 & ≤ 21 | 100.912 | 38.346         | 88.308 | 113.516 |         |        |
|           | >21 & ≤ 23 | 109.724 | 32.118         | 98.336 | 121.113 |         |        |
|           | >23 & ≤ 25 | 122.168 | 32.250         | 110.916 | 133.421 |         |        |
|           | >25 & ≤ 27 | 112.262 | 35.500         | 97.272 | 127.253 |         |        |
|           | >27        | 123.518 | 31.499         | 106.733 | 140.302 |         |        |
Table 11. Relationship between left renal dimensions and individual’s BMI (kg/m²)

| Parameters         | BMI Groups | Mean   | Std. Deviation | 95% Confidence Interval for Mean | f value | p value |
|--------------------|------------|--------|----------------|---------------------------------|---------|---------|
|                    |            |        |                | Lower Bound                     |         |         |
|                    |            |        |                | Upper Bound                     |         |         |
| **Length Left Kidney (mm)** |                   |        |                |                                 |         |         |
| ≤ 15               | 82.029     | 12.214 | 77.293         | 86.765                          |         |         |
| >15 & ≤ 17         | 90.065     | 11.306 | 85.499         | 94.632                          |         |         |
| >17 & ≤ 19         | 99.613     | 8.730  | 95.926         | 103.299                         | 14.890  | 0.000   |
| >19 & ≤ 21         | 99.482     | 11.181 | 95.807         | 103.157                         |         |         |
| >21 & ≤ 23         | 100.303    | 10.736 | 96.496         | 104.110                         |         |         |
| >23 & ≤ 25         | 102.409    | 7.637  | 99.744         | 105.074                         |         |         |
| >25 & ≤ 27         | 101.858    | 6.089  | 99.287         | 104.429                         |         |         |
| >27                | 103.944    | 10.882 | 98.145         | 109.742                         |         |         |
| **Breadth Left Kidney (mm)** |                   |        |                |                                 |         |         |
| ≤ 15               | 38.086     | 6.748  | 35.469         | 40.702                          |         |         |
| >15 & ≤ 17         | 42.200     | 7.994  | 38.971         | 45.429                          |         |         |
| >17 & ≤ 19         | 46.521     | 7.373  | 43.254         | 49.787                          | 10.919  | 0.000   |
| >19 & ≤ 21         | 47.226     | 7.014  | 44.921         | 49.532                          |         |         |
| >21 & ≤ 23         | 48.818     | 6.354  | 46.565         | 51.071                          |         |         |
| >23 & ≤ 25         | 48.629     | 5.111  | 46.846         | 50.413                          |         |         |
| >25 & ≤ 27         | 50.346     | 5.136  | 48.177         | 52.514                          |         |         |
| >27                | 49.869     | 6.510  | 46.400         | 53.338                          |         |         |
| **Thickness Left Kidney (mm)** |                   |        |                |                                 |         |         |
| ≤ 15               | 39.846     | 6.618  | 37.280         | 42.413                          |         |         |
| >15 & ≤ 17         | 43.750     | 8.163  | 40.453         | 47.047                          |         |         |
| >17 & ≤ 19         | 49.392     | 7.972  | 46.026         | 52.758                          | 7.408   | 0.000   |
| >19 & ≤ 21         | 48.274     | 9.604  | 45.117         | 51.430                          |         |         |
| >21 & ≤ 23         | 47.488     | 5.885  | 45.401         | 49.575                          |         |         |
| >23 & ≤ 25         | 51.044     | 6.348  | 48.829         | 53.259                          |         |         |
| >25 & ≤ 27         | 50.704     | 7.366  | 47.594         | 53.815                          |         |         |
| >27                | 50.400     | 6.864  | 46.743         | 54.057                          |         |         |
| **Volume Left Kidney (cm³)** |                   |        |                |                                 |         |         |
| ≤ 15               | 67.060     | 24.616 | 57.515         | 76.605                          |         |         |
| >15 & ≤ 17         | 90.221     | 32.452 | 77.113         | 103.329                         |         |         |
| >17 & ≤ 19         | 122.376    | 39.343 | 105.763        | 138.989                         |         |         |
| >19 & ≤ 21         | 123.260    | 43.036 | 107.750        | 136.041                         |         |         |
| >21 & ≤ 23         | 122.888    | 34.926 | 110.504        | 135.272                         | 13.675  | 0.000   |
| >23 & ≤ 25         | 130.973    | 31.497 | 119.983        | 141.963                         |         |         |
| >25 & ≤ 27         | 137.967    | 34.519 | 123.390        | 152.543                         |         |         |
| >27                | 138.633    | 30.155 | 122.564        | 154.702                         |         |         |
DISCUSSION

Ultrasonographic renal size is one of the easily reproducible parameter and provides rough indication of the renal function. Therapeutic decisions are frequently based on the size of the kidney. A small kidney size is an indication of irreversible chronic renal failure. Hence, it is important that the method of measuring the organ should accurate and precise. One could start with an ultrasonographic measurement of renal length and reserve MR imaging as a second-level method in case of uncertainty. When the renal length is 10 cm or longer, one would be ‘safe’ to start certain treatment or can perform certain procedure. Since the estimation of renal volume requires measurement of three dimensions of the kidney, the error increases in geometric proportion while calculating the volume. Hence it is simpler to use renal length as a yardstick for comparing renal growth with body growth [10,11].

Investigators studying intra- and inter-observer variations in renal length and volume measurements with USG have found comparable or slightly better repeatability. For example, Emamian et al. [12] found a relative SD of the difference of 4%–5% for renal length and of 14%–17% for renal volume in adults.

In the present study in 63.68%, the left kidney length was larger than right side. The kidney volume in the present study was 98.3±38.1 cm³ on right side and 115.8±41.1 cm³ on left side. This study correlate with the study of Raza et al. (2011) [11] and Arooj et al. (2011) [13]. The kidney volumes in the study by Emamian et al. (1993) [12] were larger than this study, may be due to larger habitus of the western population. In the present study, the kidney volume was found to be larger on left side in 81.17%, right side in 18.39% and equal in 0.45%. Study by Dinkel et al. (1985) found renal volume to be greater on the left in 51.7%, on the right in 29.5% and of equal size in 18.8% [14]. In the present study, the left kidney was significantly larger than the right (Table 12), which was similar to the results of many studies like Oyuela Carrasco et al. (2009) [15], Fernandes et al. (2002) [16], Dinkel et al. (1985) [14], Gavela et al. (2006) [17]. This difference could be explained by the fact that the liver being bigger than the spleen, for which the right kidney has less space to grow. Another possible explanation is related to the shorter length of the left renal artery, which increases blood flow to the left kidney which in turn increases the volume and size of the left kidney [12].
In the present study, there was sharp increase in measurements of parameters till the age of 20 years and slight increase up to 30 years and thereafter, it remained stable beyond 30 years up to 50 years. The above analysis leads us to formulate the hypothesis that the parameters of kidney might have attained its full growth by the age of 11-20 years and corroborates with the findings of Buchholz et al. (2000) [2]. Han and Babcock modelled renal growth according to two separate linear models—one from birth to age 1 year and another from age 1–18 years. Their model estimates growth to be 0.15 cm per month in the first year and 0.27 cm per year thereafter [18]. A decline in trend in all the measurements of parameters beyond 50 years was observed in the present study similar to study by Reshaid and Fattah (2014) [19]. However, the mean volume on both sides had a slight increasing trend in the age group 61-70 years, which may be due to relaxation of the abdominal wall with advancing age, so that the kidneys are squeezed less in older persons.

In the present study, it was found that all the parameters of kidney in male were larger than female on both sides and differed statistically significantly. This corroborates with the result by Raza et al. (2011) [11], Emamian et al. (1993) [12], Arooj et al. (2011) [13], Hekmatnia and Yaraghi (2004) [7], Oyuela Carrasco et al. (2009) [15], Fernandes et al. (2002) [16], Gao et al. (2011) [20], Mustafa and Ahmed (2017) [21]. In this present study, all the parameters of kidney correlates well with height, weight and BMI and are statistically significant (p=0.000). However, best correlation was found with height and weight. Raza et al. (2011) also showed a significant positive relationship of the subject’s height and weight with renal volume and renal length in both genders [11]. This finding is very much in line with the studies of many workers such as Emamian et al. (1993) [12], Gavela et al. (2006) [17], Buchholz et al. (2000) [2], Fernandes et al. (2002) [16] and Oyuela Carrasco et al. (2009) [15]. However Reshaid and Fattah (2014) observed that renal length of the two sides correlate in a significantly positive manner with weight and BMI, and weakly with height [19], in contrast to other studies in adults where the strength of this association has been significantly greater with height [12,15,20].

The data in the present study show that the mean values obtained for the dimensions of both kidneys was similar to the study done by Raza et al. (2011) [11], Buchholz et al. (2000) [2] and Zeb et al. (2012) [22] as the population under these studies, belonged to South East Asia. The mean values were below those found in European studies. It is known that the Westerners are taller and bigger compared to Asians [13]. The organs of Asians are generally accepted to be smaller than that of Westerners [23].

**CONCLUSION**

In this study in all age groups the ultrasonographic mean dimensions of right kidney were length 94.4 ± 11.8 mm, breadth 41.2 ± 7.9mm, thickness 46.2 ± 9.5 mm and volume 98.3 ± 38.2 cm³ and the mean measurements of left kidney were length 97.4 ± 12.1 mm, breadth 46.4 ± 7.6mm, thickness 47.5 ± 8.2 mm and volume115.8 ± 41.1cm³. The parameters were
smaller than previously reported, is probably a reflection of the relatively small body size of South East Asians than western population. Left kidney was larger than Right kidney. Kidneys were significantly larger in male than female. All the measurements of parameters of both right and left kidney correlated significantly with age, height, weight and BMI. Maximum growth period noted in this study was up to 20 years of age. Thereafter, there was minimal growth up to 50 years. Slight decline in trend in all the measurements of parameters beyond 50 years was observed.

Conflict of Interest: None

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