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Relation between Renal Length and Renal Volume with Patient's BMI: A Critical Appraisal

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Abstract

In urological and nephrological practices, evaluation of kidney size imparts a valuable diagnostic parameter. Age, gender, body mass index, pregnancy and co-morbid conditions such as diabetes mellitus, hypertension are supposed to affect the renal size. Measurements of renal dimensions can be carried out by using different modern techniques like ultrasonography, CT scan and MRI. On the other hand body mass index (BMI) provides information to know the patient's obesity which is based on patient's height and weight. Information available from one particular region may not satisfy the other region as renal parameters varies with different ethnic group and body size. In this prospective, reviewing literature of different studies evaluated so far to predict the relationship between renal dimensions and BMI is carried out. These studies revealed that most of renal parameters were positively correlated with body size of an individual, therefore they can be used to estimate the size and volume of kidney. Moreover, the standard normal reference ranges for renal volume and size can serve as gold standard and acts as an adjunct to judge the atrophic or hypertrophic condition of kidney. Hence, establishing relationship between measured renal dimensions and BMI will serve as a useful guideline for detection of diseased condition of kidney. This paper sets out to present published data on researches that has fortified knowledge and understanding of correlation between different renal parameters and BMI, keeping in mind different demographic background. Thus here we are putting a comprehensive account of the studies carried out globally to establish the inter-relationship between renal dimensions with BMI which definitely helps the nephrologists in early diagnosing the renal diseases.

Keywords: Renal length; Renal volume; Body mass index

Introduction

Systemic diseases like diabetes mellitus and hypertension rising globally and are the leading cause of end stage renal disease (ESRD). Multiple renal diseases like nephrolithiasis, hydronephrosis, chronic renal diseases, and renal tumors along with end stage renal disease alters renal dimensions leading to changes in the size and shape of kidney [1,2]. Thus estimation of renal size is a vital criteria in the diagnosis, treatment and evaluation of renal disease [3]. Renal size estimation most commonly includes renal length, renal volume and cortical thickness [4]. For everyday practice, renal length measurements are more reliable because of its easy reproducibility [5] but most accurate being the renal volume measurement. Moreover, renal volume is also considered as the excellent predictor of renal function [6]. Renal dimensions measurement is widely carried out by ultrasonography (USG) because of its accessibility, non-invasive and easy reproducibility [3,7]. Few studies have shown that computed tomography (CT) can acquire renal dimensions more accurately than USG [1,8,9]. But the use of ionizing radiation and contrast media for measurement of renal dimensions limits its place as a non-invasive procedure on daily basis [6,8]. On the other hand, MRI (magnetic resonance imaging) can also predict 3-dimensional data without any ionizing radiation but very little data is available regarding renal dimensions [8,10], as it is very expensive and not readily available.

Different studies had shown that anthropometric measurements like height, weight and body mass index (BMI) correlates very well with renal length and volume [1,3-5,11]. Renal dimension varies according to subject's body habitus [9] and according to ethnicity [12]. These variations can be expressed by prediction model depending on height and weight of the subject, which can be used as a reference value in clinical practice for a particular population group.

- Renal size (mm)=49.18109+0.2060×weight (kg)+0.27360×height [9].
- Right renal length (cm)=6.44+1.13×height+0.03×weight [13].
- Left renal length (cm)=6.94+1.01×height+0.02×weight [3].

So from the earlier discussion it has been revealed that, prediction of renal dimensions can also be achieved by the knowledge of anthropometric data of a patient. Hence, unnecessary evaluation and exposure to toxic effect of the different imaging modality can be avoided, as a large number of Indian populations reside in rural area. Thus it is very much cost effective and do not impart unnecessary economic burden to people residing in a developing country like ours. Here we are reviewing correlation between BMI and renal dimensions (renal length and renal volume) measured by different imaging modalities. Thus, we are trying to provide a series of information under the above mentioned heading which may indirectly help our society. Renal dimension measurements either in the form of renal length or renal volume, are important parameters for clinical evaluation of diseased condition [13,14]. As renal length correlated best with body indexes [1], and renal size is directly proportional to the increased BMI [15], clinician can get a rough idea of renal dimensions with the help of anthropometric measurement which can act as a guide for diagnosing the renal pathology and early interventions, thereby an adjuvant to the modern techniques.

BMI Influencing Renal Length

Renal length is the most frequently used renal measurements for comparison with data published in a standard literature for clinical evaluation of kidney diseases [1]. Renal length varies with various factors like age, gender, and ethnicity, anthropometric measurements like height, weight, BMI and gestational age also [3,7]. Moreover renal diseases can also change the morphological features of kidney [7]. Now-a-days obesity is considered for adults if BMI ≥ 30 kg/m^2 [2] and it is associated with various co-morbid conditions which ultimately affect the health status of general population. Increased BMI is responsible for high prevalence of HTN, DM, and many other risk factors which ultimately leads towards (end stage renal disease) ESRD [2,16]. The prevalence of obesity is increasing globally [16]. BMI (Body mass index) is one of the most commonly used parameters to measure the degree of obesity [16,17]. BMI was calculated using the formula, weight in kg and height in m^2 [18]. Renal length can be measured by using USG, CT and MRI. In ultrasonography, renal length was measured as the longest distance from superior pole to inferior pole [5,15,19]. In CT, maximum diameters in oblique coronal planes were used to obtain the maximum renal lengths [1,9]. According to Cheong et al. [8] MRI estimates the kidney length as the length of the long axis of each kidney measured along the cranio-caudal direction. As renal length is an important parameter for clinical evaluation of renal disease, here we are reviewing articles revealing significance of renal length in accordance to BMI in different age, sex and ethnic group.

A total number of 712 school-aged children in the age group of 7-15 years were screened ultrasonographycally to evaluate the relationship with organ dimensions and anthropometry by Safak, et al. [20] after obtaining written consent from the parents, organ dimensions of liver, spleen and kidney were made during deep inspiration. In case of kidney, measurements were done in lateral decubitus position and renal hilum was visualized to get the maximum longitudinal dimension. Mean of the three times reading was considered as the absolute length. Statistical analysis showed that organ dimensions had (renal length in case of kidney) the weakest correlation with BMI.

A total number of 153 healthy Mexican adults underwent ultrasonography to evaluate the relationship between renal lengths (RL) with anthropometric measurements by Oyuela-Carrasco, et al. [7] renal length was measured as the longest longitudinal diameter in empty bladder in three positions (supine, supine-lateral, and prone). The longest length among these three measurements was taken as absolute renal length. Average left renal length (LRL) in male and female group was 107.16 ± 6.97 mm and 104.6 ± 7.96 mm respectively. The average right renal length (RRL) in male and female group was 105.74 ± 5.74 mm and 102.99 ± 6.85 mm respectively. Mean weight of the study group was 68.87 ± 11.69 kg. The average height of the study group was 160 ± 8.62 cm and average BMI (body mass index) was 26.7 ± 3.82 kg/m^2. The correlation coefficient of LRL (left renal length) with BMI was r=0.408 and for RRL (right renal length) was r=0.363, using Pearson correlation assessment. It showed a significant positive correlation between both renal lengths with body mass index (BMI). Zuuzuarregui et al. [21] postulated that body mass index (BMI) is greatly correlated with renal length in their study named ''the effect of obesity on kidney length in a healthy pediatric population". A total number of 204 healthy patients were screened for benign hematuria. Among them 59 obese patients had larger renal lengths (both right and left) than their normal weight counterparts. According to this study, both right and left renal lengths significantly correlated with body mass index (BMI) in obese group [21]. Influencing factor of normal renal dimension was carried out by Glondy et al. [22] on 1040 adults without any renal disease using MDCT (multiphase thin slice CT). Kidney length pole to pole (LPP) and in axial slice were measured. Mean right kidney length (LPP) was (108.5 ± 12.2) mm and left kidney length was (111.3 ± 12.6) mm. Axial plane lengths in case of right side was (57.7 ± 8.0) mm and in left side was (53.6 ± 8.2) mm. Body mass index for each patient was also recorded. Linear correlation was found between body mass index (BMI) and LPP and it was also observed that kidney length increases with increases in BMI.

Determination of relationship between renal length and BMI (body mass index) was carried out by Kim, et al. [23] for this purpose, 550 children, between 1 month and 15 years of age were recruited without any renal disease. Renal length was measured using ultrasonography and mean of the three readings were taken for both right and left kidney. This study produced regression equation to predict renal length in relation to BMI. The equation is,

renal length (mm)=44.474+1.163×BMI (r^2=0.079)

It shows that renal length is related with BMI [23]. Harmse, et al. [9] estimated relationship between renal length and anthropometric measurements of 514 adult patients without any renal disease. Kidney lengths were measured by using oblique coronal 8-slice CT images and anthropometric measurements like height, weight and body mass indexes (BMI) were recorded. BMI was calculated as weight in kg divided by height in meters squared. Mean renal size (kidney length) for male and female were 110.1 mm and 108.9 mm respectively. By regression analysis, a significant positive relation was found between kidney size (kidney length) and weight of the patient. It was observed that 0.2564 units increase of kidney size was associated with a unit increase in the weight of the patient. This regression model also showed that weight of the patient can explain 24.64% of the kidney size variation. Another linear regression model also showed that 0.42180 units increase in kidney size (kidney length) was associated with one unit increase in BMI. However, in this regression model BMI can explain only 8.7% of the kidney size variation [9]. A total number of 4,083 subject underwent abdominal and genito-urinary diagnostic ultrasonography to evaluate the relationship between absolute renal length (ARL) and body mass index (BMI) in adults without known renal disease by Raza, et al. [11]. Maximum bipolar dimension in longitudinal axis was measured as renal length. Mean of the three times readings was taken for each kidney. Absolute renal length (ARL) was taken as longitudinal dimension of kidneys in millimeter (mm). Mean ARL for right kidney was 101.6 ± 8.9 mm and for left kidney was 102.7 ± 9.2 mm. Mean height of the men was 172.6 ± 6.9 cm and for women was 155.2 ± 5.9 cm. Mean weight for men was 76.3 ± 14.4 kg and for women was 67.1 ± 13.9 kg. Ratio of absolute renal length (ARL) and subject's absolute body height in cm was taken as relative renal length (RRL). Mean BMI of the study group was 26.8 ± 5.45 kg/m^2. Pearson's correlation coefficient (r) test was used to evaluate the relationship between renal sizes with BMI. For both the kidneys, a direct positive but weak linear relationship was observed when ARL and BMI were compared. A significant increase in ARL was also seen with increased subject's BMI [11].

Elsayed et al. [24] performed a study on 100 adults Saudi volunteers to establish the relationship between kidney length and body mass index with the help of ultrasonography, in patient who does not have any known renal disease. Kidney length was measured as the major distance between the superior and inferior renal poles in USG. Images were taken after voiding bladder in supine position, to avoid pelvicalycal increase caused by oral hydration. Average renal lengths of

both the kidneys were 9.91 ± 0.85 cm for right kidney and 10.17 ± 0.89 cm left kidney. Average height for male and female were 174 cm and 164 cm respectively. Statistical analysis was done using SPSS programme and it revealed that significant increase of right and left renal lengths were associated with increased BMI with p=0.0000 [24]. Hammad et al. [25] estimated relationship between renal length and body mass index (BMI) of Saudi adults using sonography, without any known renal disease. Mean height of male was 1.72 m and female was 1.57 m. Mean weight of male and female were 63.76 kg and 60.3 kg respectively. Renal length was measured as the longest longitudinal diameter in USG images. Mean length of right and left kidney were 10.32 cm and 10.77 cm respectively. Pearson correlation coefficient was used to examine the association between kidney dimensions (renal length) and BMI. In this study, a moderate positive correlation between BMI in females with left kidney length was observed. A moderate positive correlation was found between weight of the patient and left renal length. But in case of female, the correlation was found between BMI and left renal length [25]. Sultana, et al. [26] evaluated relationship between kidney length and anthropometric measurement of 100 new-born, healthy, term infants using ultrasonography. After obtaining written consent from the parents, anthropometric measurements like birth weight, length and occipito-frontal circumference (OFC) of each baby were recorded. Mean birth weight was 2.98 ± 0.374 kg. Correlation value of the infant's kidney length with infant's height was 0.085. Maximum longitudinal diameter was considered as the renal length. Mean renal length for right and left side were 39.22 ± 4.34 (mm) and 38.36 ± 4.30 (mm) respectively. In this study, it revealed that neonatal kidney length correlated significantly with infant's BMI (where p value remains <0.0001) [26].

A study in Nigeria showed that kidney dimensions (bipolar length) correlated best with BMI (body mass index) by Udoaka, et al. [27] the aim of the study was to determine the normal organ (liver, spleen, kidneys) dimensions in relation with anthropometric parameters of healthy adult Nigerians. A total number of 723 subjects were screened ultrasonographycally and their anthropometric measurements were also recorded. BMI was calculated for every subjects in kg/m^2. Bipolar length (BPL) and transverse diameter (TD) were viewed in prone position of both kidneys in every subject. Mean bipolar length in left kidney was (10.31 ± 1.10) cm and in right kidney was (10.02 ± 0.97) cm. It was concluded by the author that BMI has strongest correlation with renal dimensions than other organs like liver and spleen [27]. Healthy 215 Sudanese school aged children (7-13) years underwent USG examination to correlate kidney length with anthropometric measurements by Ayad, et al. [28] renal length was measured in supine and contralateral decubitus positions for respective kidneys. Maximal longitudinal renal length was measured in sagittal plane. The study reveals that left kidney length was 7.9 ± 0.8 (cm), 8.1 ± 0.7 (cm) and right kidney length was 8.0 ± 0.8 (cm), 8.3 ± 0.8 (cm), for men and women respectively. Anthropometric measurements like height, weight, abdominal circumference and body mass index (BMI) were also recorded. In this study, authors had established prediction models of the kidney lengths of corresponding side in millimeters according to BMI and these are:

a) Left kidney length=0.01×child BMI+6.72, r^2=0.05

b) Right kidney length=0.08×child BMI+6.72, r^2=0.13 [28]

Eze et al. [29] estimated kidney dimensions among 947 apparently healthy school age children using sonography. Kidney dimensions obtained in coronal plane passing through the renal hilum, three times and the mean values were recorded. Images were taken during deep inspiration with the subject in supine position. The mean kidney lengths were 79.6 ± 8.1 mm and 81.61 ± 8.32 mm for the right and left kidney respectively. Anthropometric data like height and weight of the study group were also recorded. Body mass index (BMI) was measured as BMI=weight in kg/height in m^2. The mean height of the study group was 140.24 ± 17.93 cm and the mean weight of the study group was 34.88 ± 12.33 kg. Mean BMI was17.10 ± 2.06 kg/m^2. Pearson correlation coefficient of kidney length with BMI was r=0.688 which showed a moderate negative correlation and weight showed a moderate positive correlation where correlation coefficient is r=0.889. They explained it on the basis of rapid body growth that occurring before the attainment of mature body morphology at adult stage [29]. El-Reshaid et al. [30] estimated sonographic values of renal dimensions in 252 patient aged 18-80 yrs. without any renal disease in Kuwait. Renal length was measured as the longest longitudinal diameter. Anthropometric data like height and weight were also recorded. The mean renal lengths of the study group were 10.68 ± 14 cm and 10.71 ± 1.0 cm for right and left kidney respectively. Mean height and weight of the study group were (143-193) cm and (37-124) kg respectively. The renal length showed strongest correlation with BMI (where p value p<0.01) and weight of the patient (p<0.01). Pearson correlation test also showed that renal length increased by 0.23 cm for each 10 kg increase in body weight within the range of 60-120 kg. The explanation given by the authors was that larger body size requires a larger nephron dose to meet its metabolic demands [30].

Younus et al. [31] ultrasonographycally evaluated relationship between renal length and anthropometric measurements among 150 children of 1 month-14 years age group, without any renal disease. Anthropometric data were recorded. Renal lengths were obtained in sagittal view with children in supine or contralateral decubitus position, without any preparation or sedation. Taking height as the independent variable and renal length as the dependent variable, regression analysis for right and left kidney lengths were (R^2) 0.424 and 0.443 respectively. It was observed by the authors that both right and left kidney lengths moderately and significantly correlated with weight of the individual and moderately insignificant with body mass index (BMI). BMI was not related to kidney length; it is due to the fact that the sample size selected was in rapid growth stage [31]. Srivastava et al. [32] estimated relationship between renal length and anthropometric measurements among 100 adult healthy voluntary kidney donors without any renal disease. All of them underwent multi-detector computed tomography (MDCT) and CT angiography for measurements of renal length. Mean renal length was taken after obtaining renal length in three different section, that is in axial, coronal and sagittal section. Mean renal length were 99.2 ± 9.71 mm for left kidney and 95.3 ± 8.44 mm of right kidney. It was shown that there was no correlation between renal length and body weight of the individual and also no relation between BMI [32]. Thus these observations were in agreement with the studies conducted by Eze, et al. [29] and Younus et al. [31] 50 obese and 50 non-obese children and adolescent aged 1-19 years were included in a study for estimation of relationship between renal length and body mass index (BMI) by Soheilipour, et al. [2] 100 children and adolescent were screened ultrasonographycally and the longest longitudinal measurement in deep inspiration was taken as the kidney length. Mean height of the control group was (144.44 ± 23) cm and for obese group was (145.9 ± 22.05) cm. Mean weight of the control group was (39.20 ± 15.96) kg and for obese group was (67.02 ± 24.83) kg. Mean BMI of the control group was (17.74 ± 2.21) kg/m^2 and for obese group was (29.54 ± 5.14)

kg/m^2. They recommended BMI as significant predictors of kidney length [2].

Myint, et al. [33] established relationship between ultrasonographycally measured renal dimensions and BMI among 321 healthy students in Malaysia. The age of the study group was 19-25 years. After obtaining written consent sonographic renal measurements were carried out and these are renal length, width and renal parenchymal thickness. Anthropometric measurements were also done. According to BMI the sample size was divided into four categories and these are normal BMI (64.3%), underweight (15%), overweight (12.9%) and obese (7.8%). Mean renal length was 9.81 ± 0.75 cm in case of right side and 9.85 ± 0.58 cm in case of left side. Statistical analysis of the study revealed that renal length significantly correlated with BMI and correspondingly increased with increased BMI which coincided with the most of the past researches [33].

Above discussion clearly signifies that extensive studies has been carried out in different countries involving different age, sex and ethnicity to establish correlation between renal length and BMI. Among 18 different studies, most of the studies revealed significant positive correlation between renal length and BMI among particular population group [2,7,9,21-28,30,33]. In five studies we were failed to find any significant relationship [11,20,29,31,32]. Hence, a larger population group has to be included in the study for a particular demographic area to find out any effective relationship between renal length and BMI.

BMI Influencing the Renal Volume

Kidney volume is an important parameter for clinical evaluation of diseased conditions like DM, renal artery stenosis and chronic kidney diseases [1,2,8]. It is also an important clinical parameter for follow up patients of kidney transplantation [34]. Renal volume is considered to be a more sensitive index of detecting renal mass than any other measurements [35]. Renal volume also changes according to sex, body size, anthropometric measurements (height and weight), BMI and ethnicity [3,7]. Renal volume is measured by different methods in different studies and most commonly used method is the ellipsoid method and another is the water displacement method [1,6,8,10]. As renal volume is an important criteria for evaluation of renal disease, renal volume has to be assessed in accordance with BMI. So, we are providing a series of information related to this.

A total no of 194 subjects between 13-80 years of age, without any renal disease were evaluated ultrasonographycally to determine the renal dimensions and its correlation with age, sex and BMI by Buchholz, et al. [36] renal dimensions included renal length (distance pole to pole), width (transverse axis) and cortical thickness. Kidney size was measured using the formula (length×width×cortical thickness). Mean kidney size was 76.16 ± 21.7 cm^3. Statistical analysis revealed a strong correlation between renal size and BMI and it also showed that renal size increased correspondingly with increased BMI, only in case of left kidney [36].

Schmidt, et al. [37] evaluated relationship between kidney volume and lean body mass where kidney volume measured by ultrasonography and body composition by dual energy x-ray absorptiometry. They concluded that lean body mass was the strongest predictor of kidney volume in healthy 10 year old children [37].

Egberongbe et al. [10] evaluated relationship between renal volume and anthropometric measurements in 150 essential hypertensive and 50 normal healthy adults using ultrasonography in South- westerns Nigeria. Anthropometric data like height, weight, BMI, age, sex along with duration of hypertension were also collected. In sonography, renal length (L) was measured as the longest distance between the superior and inferior poles. Antero- posterior (AP) diameter was measured as the maximum distance between the anterior and posterior wall of kidney at the mid-third position. Renal width (W) was measured as maximum transverse diameter on transverse scan. Renal volume (RV) was calculated using the formula=L×W×AP×0.523. Mean left kidney volume was 114.06 ± 29.78 cm^3 and right kidney volume was177.50 ± 47.37 cm^3. Statistical analysis showed a significant correlation between renal volume and BMI in both hypertensive and control group [10].

Hammad, et al. [25] established relationship between anthropometric measurements and renal dimensions in young Saudi population of age group 19-28 year without any known renal disease. After obtaining ethical permission and written consent all participants underwent USG examination in empty bladder, so that an increase in renal length caused by oral hydration can be avoided. Anthropometric data were also recorded. Renal length was taken as the longest longitudinal diameter and renal width, thickness and cortical thickness were measured in longest absolute terms. Renal volume was measured using the formula,

RV=renal length×width×thickness×0.5

Pearson correlation test was used to examine the relationship between renal dimensions with anthropometric measurements. It was concluded that, in case of female there was a moderate positive correlation between right kidney volume and BMI [25].

Renal ultrasound measurements were performed on 150 healthy, normal, pregnant women in a study carried out by Ugboma, et al. [38] renal measurements included in the study were renal length, width, thickness and renal volume. Height, weight and BMI were also recorded. Renal length was measured as the longest longitudinal diameter in between the superior and inferior pole in longitudinal scan. Width was calculated as the maximum diameter on transverse scan at the level of hilum and thickness was measured as the maximum distance between the anterior and posterior walls of kidney in longitudinal scan. Renal volume was measured using the ellipsoid formula. The average left kidney volume was 163.44 ± 51.3 cm^3 and right kidney volume was 141.85 ± 41.07 cm^3. A significant positive linear correlation was found between renal volume and BMI in case of both left and right kidneys and it was also postulated by the authors that renal volume increases with significant increase in BMI [38].

340 healthy adults (age range from 18-30 years) volunteers were included in the study for determination of renal dimensions and its correlation with anthropometric measurements by Gupta, et al. [39] All participants underwent USG examination after emptying bladder, so that an increase in renal length caused by oral hydration can be avoided. Renal measurements included renal length (distance pole to pole), renal width (in transverse axis), cortical thickness, in millimeter and also kidney size (kidney volume)=length×width×cortical thickness. Anthropometric data were also recorded. Mean body weight were 60.5 ± 9.5 kg and 52.2 ± 8.4 kg for male and female respectively. Mean height of the male group was 162.9 ± 8 cm and for the female group was 152.9 ± 6.1 cm. Finally they concluded that the mean renal size significantly correlated with BMI and renal size correspondingly increased with BMI [39,40].

An ultrasonographic study performed on Nigerian children also revealed statistically significant relationship between renal sizes (renal length and volume) with BMI by Eze, et al. [40]

Forensic autopsy was done on 114 male deceased between 25-88 year of age to study the relationship between organ volume, weight and size with its anthropometric parameters like height, weight and BMI by Caglar, et al. [41] Body weight was measured by using electronic weighing scale and height was measured as the distance between the top of the head and heal in measuring scale. Organs (pancreas, spleen, and kidney) weight were also measured by using the same electronic weighing scale. Organ's volume were measured by using Archimedes principle of water displacement method by submerging the organ in a water filled scaled measuring bowl. Mean height of the study group was 172.2 ± 7.5 cm, weight was 78 ± 15.2 kg and the average BMI was 26.2 ± 4.7 kg/m^2. They finally concluded that, for the kidney, organ volume strongly correlated with BMI [41].

A study was carried out on 98 patients who underwent MRI to establish reference values for renal length and renal volume using MRI disc summation method and to correlate the measurements with body indexes by Abdullah, et al. [6] Data included in the study were age, gender, weight, height, body mass index (BMI) etc. Renal dimensions included were renal length, width and depth. Renal measurements were done in three axis assuming kidney to be a cylinder and calculated length in Z axis, width in X axis and depth in Y axis. Renal length was measured as RL= number of slices (in which kidney appears) × slice thickness (cm). Renal width was calculated as RW=$\sqrt[3]{}$ total kidney volume (in x- axis). Renal depth RD=$\sqrt{}$ largest area (mm^2)/10, (in y-axis). Renal volume was measured as RV (cm^3)=length×depth×width. Statistical analysis had shown that there was strong positive relationship between BMI and kidney volume on both side and prediction model was,

a) Right kidney volume=1.096× BMI+131.0

b) Left kidney volume=1.062× BMI+132.6 [6]

A total number of 450 adult volunteers without any renal disease were included in the study conducted by Karim, et al. [15] for estimation of renal size and to correlate it with anthropometric variables like height, weight and BMI. Renal measurements include renal length (distance from pole to pole), renal width (distance between medial and lateral border of kidney) and cortical thickness (distance between outer renal margin and renal sinus in transverse plane) and also renal volume using the formula, renal size (mm^3)=renal length×width×cortical thickness. Body mass index (BMI) was measured using the formula, BMI=weight (in kg)/height (in m^2). Mean kidney size of the left kidney was 89031.0296 mm^3 and of the right kidney was 72210.9842 mm^3. Mean BMI of the study group was 27.1622 kg/m^2. Pearson correlation showed a significant positive correlation between BMI and kidney size of both kidneys [15].

A study was conducted on 84 renal donors to estimate the renal volume and to correlate it with different body indexes by Rathore, et al. [42] Renal volume measurements were done by using two different methods.

a) Ellipsoid method= π/6× length× width× thickness

b) Displacement method (after donor nephrectomy)

Renal dimensions were (renal length, width and depth) measured in his study using the helical CT scan images. Anthropometric data like height, weight and BMI of the donor group were recorded. Mean BMI of the study group was 24.70 ± 3.4 kg/m^2. Researchers observed that mean renal volume calculated by ellipsoid method was less than renal volume measured by displacement method. This study also revealed that there was a strong correlation between BMI and renal volume measured by both methods [42].

A total no of 104 adult volunteers underwent ultrasonographic renal measurements without any renal disease in a study conducted by Maaji, et al. [43] Somatic parameters like height, weight, age, sex and body mass index were recorded. Renal measurements included renal length, width, thickness and renal volume. Renal length was calculated as the maximum longitudinal diameter in cranio-caudal direction in sagittal plane. Width was measured in transverse section perpendicular to the longitudinal length and distance between the ventral and dorsal surface of the kidney was considered as renal thickness. Renal volume was calculated by using ellipsoid formula. The average renal length for the study group was 11.3 ± 8.8 cm and 11.6 ± 9.8 cm for right and left kidney respectively. The mean width of the right kidney was 4.4 ± 0.71 cm and left kidney was 5.2 ± 5.26 cm. The average right renal thickness was 4.7 ± 0.67 cm and left renal thickness was 4.5 ± 0.68 cm. Mean right kidney volume was 109.6 ± 29.3 cm^3 and left kidney volume was 119.7 ± 32.8 cm^3. The average height of the subject group was 1.67 ± 0.85 m and average weight was 70.9 ± 11.2 kg. The average BMI calculated were 25.1 ± 3.96 kg/m^2 and 26.0 ± 5.36 kg/m^2 for female and male respectively. Pearson correlation test was applied to assess the relationship between renal measurements and body indexes and it showed that there was positive relation between renal volume and BMI [43].

Tatar, et al. [44] evaluated relationship between renal volume and BMI in obese and non-obese kidney donors. Renal volume was explored by using computed tomography in 82 kidney donors and mean renal volume of the study group was 196 ± 36 cm^3. The average body mass index (BMI) was 28 ± 4.2 kg/m^2 for the study group and among them 32.9% were obese. In this study it was observed that renal volume was strongly correlated with BMI, which agrees with most of the previous studies [44].

Another study done by Cheong, et al. [8] revealed that there was no correlation between kidney volume and BMI.

A study of correlation between anthropometric measurements and renal dimensions using ultrasonography was carried out by Kim, et al. [45] A total number of 794 Korean children underwent sonographic evaluation without any renal disease. Anthropometric measurements like height, weight and BMI were recorded. Renal dimensions included renal length, width, depth and renal volume. Renal volume was measured by using the ellipsoid formula,

renal volume=lengt×width×depth×0.523

Statistical evaluation by Multivariate analysis showed that renal volume had no relation with BMI [45].

Okur et al. [46] was to evaluate the relationship between kidney volume and body parameters. Renal volume in his study was measured by using ultrasonography as it is widely available for daily practice. Renal dimensions (renal length, width and thickness) were measured with the subject in prone position. Total renal volume was measured using the formula,

RV=length×thickness×width×0.523

Body parameters (age, sex, height, weight and body mass index) of 152 patients were also obtained. Mean right kidney length was 10.3 ±

7.8 cm and left kidney length was 10.4 ± 9 cm. Mean right kidney volume was 158 ± 39 cm^3 and left kidney volume was 168 ± 40 cm^3. BMI for women was 27 ± 6 kg/m^2 and for men was 28 ± 5 kg/m^2. Pearson correlation co-efficient were used to evaluate the relationship between renal dimensions with other parameters. They observed a weak correlation between left kidney volume and BMI [46].

A study was conducted on 93 patients by Lavanya et al. [47] using oblique coronal reformatted CT images without any renal diseases. Somatic parameters like height, weight BMI were also measured. Mean left renal length in case of male was 95.42 ± 6.76 SD and right renal length was 94.6 ± 7.45 SD. In case of female, mean left renal length was 97.56 ± 6.88 SD and right renal length was 96.82 ± 7.73 SD. No relation was found between renal size and body habitus and it was concluded that renal size was independent of BMI, which concurred with the studies carried out in the past [1,45]. Several researches reported that increased BMI was closely associated with the increased risk of developing chronic renal disease as well as ESRD (end stage renal disease) [48-50].

Thus from the above reported researches it clearly presented that significant relationship exists between renal volume and patient's BMI which was seen in about thirteen studies conducted in different geographical locations [6,10,15,25,36-44]. But no such correlation was found in some of the studies which may requires more number of individuals to be participated in the study [8,45-47].

Conclusion

From the above discussion we are getting a clear idea about relation between renal length and renal volume with body mass index (BMI). Many studies have shown that renal length and volume are greatly influenced by patients BMI. On the other hand there are few studies available which did not reveal any significant correlation between renal length and volume with patient's BMI. Thus the most significant factor associated with renal volume is BMI. All these studies were done in demographic locations involving different age, sex and ethnic groups. Moreover, renal dimensions measurements were carried out by using different newer imaging modalities like USG, CT and MRI. So, our recommendation is that study should be carried out specific for age, sex and particular population group to find out the normogram of renal dimensions for clinical use in a particular geographic area by using a specific technique.

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