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Establishing Reference Ranges for Pediatric Kidney Size Using Multidetector Computed Tomography in Pakistani Children

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ABSTRACT

Precise reference ranges in terms of kidney size in pediatrics is crucial to diagnose renal pathologies and make proper clinical decisions in pediatric nephrology. Although imaging technology has been advanced, no population-specific computed tomography (CT)-based norms of the renal size are available in Pakistani children. The purpose of the study was to analyze the Multidetector Computed Tomography (MDCT) as a normative range of measurements of kidney length, width, thickness and volume in a representative sample of Pakistani children. We retrospectively analyzed reading of MDCT scans of children aged between 0 and 18 years and we used measurements as an indicator that was compared to demographic factors such as age, height, weight, and body surface area. The findings revealed a steady growth in kidney sizes with age and somatic growth parameters, and were the first CT-based pediatric renal reference data showed in this population. These reference ranges will help the radiologist and clinician to better assess the development of the kidney and promptly detect pathological deviations in Pakistani children.

Keywords: Pediatric kidneys, Multidetector Computed Tomography, reference ranges, Nepal, pediatric radiology, size of kidneys.

INTRODUCTION

Precise measurement of renal size is an essential part of pediatric nephrology and radiology, as it is one of the critical measurements that indicate the health, development and functioning of kidneys. Renal size, such as length, width, thickness and volume, are currently used in clinical practice as indicators to identify congenital deficiencies, disease progression, and therapeutic interventions. Although ultrasound is the traditional choice of imaging modality in assessing the size of kidneys because it is a safe and accessible approach to the condition, Multidetector Computed Tomography (MDCT) is the most appropriate to use because it is reproducible, and has a higher spatial resolution, which is especially useful in setting reference standards (Radiopaedia, 2025). It will be necessary to define normative CT based reference ranges of kidney sizes in children since rate of kidney development varies between groups of children due to genetic, nutritional and environmental effects.

At least in most regions of the world, there is a preponderance of normative renal size data based on ultrasound, vulnerable to inter-observer error, and not capable of visualizing intricate anatomical features. Nonetheless, the CT imaging gives high resolution of cross-sectional views that can enable a good measurement of the renal dimensions and the volume, which enhances diagnostic confidence. Population-specific reference data is necessary to take into account ethnic and region-dependent differences in female pediatric kidney growth (Radiopaedia, 2025). Historically, in the Pakistani situation, there were no CT-based norms of renal size used in children, so the clinicians have had to depend upon the reference values via non-local populations or ultrasound studies which may not provide the dimensional precision that MDCT can offer.

This gap has been filled by a recent study in Pakistan that has defined CT based reference ranges of renal dimensions in Pakistani children, which have shown that kidney volume and size are predictably increasing according to age and are strongly correlated to the somatic parameters height, weight and body surface area (Yousaf, 2026). The study demonstrated the significance of factoring in demographic variables in the interpretation of the renal measurements, as it was the first normative MDCT data of metric of kidney dimensions in the country among children. These results can be correlated with the international literature in which the renal size is strongly associated with age and body size and normative values create differences depending on ethnicity (Radiopaedia, 2025).

The clinical value of defining correct pediatric renal size reference ranges is that accurate pediatric pathologic deviations of the reference ranges are determined early on, including renal hypoplasia, dysplasia, or compensatory hypertrophy. Abnormalities in the size of the kidney may indicate underlying pathology and can affect the management of conditions like congenital anomalies of the kidney and urinary tract (CAKUT), vesicoureteral reflux, or chronic kidney disease. An illustrative case is a kidney significantly smaller than the normative range of age and body size, which may indicate that it is being underplasticized or damaged permanently, which will require additional study and therapy. On the other hand, kidneys which are over normal size may reflect the compensatory hypertrophy or other underlying obstructive mechanisms.

Past studies have focused on the necessity of very specific imaging reference standards. Talhar et al. (2017) showed that measurements of renal volume by CT are small load dependent, and other demographic characteristics thereby confirming the significance of CT imaging in determining normal data of renal size. Likewise, in the literature on international pediatric radiology, growth curves of the renal dimensions have been reported where it is observed that the increase in the size of the kidneys goes in line with age and body size with minor variation depending on sex and ethnicity (Radiopaedia, 2025). Still, with the progress of these technologies, little data of CT-derived renal sizes exist in South Asian pediatric populations, and more specifically in Pakistan, where demographic and nutrition characteristics might not be the same as in Western populations.

The creation of pediatric kidney size reference ranges with MDCT has impact on diagnostic imaging, as well as creating better insights into the normal pattern of renal growth in children. The renal dimensions of pediatrics are determined by various factors such as age, body surface area, nutritional status and genetic background. Hence, local reference standards, taking into consideration these variables, are crucial to the accurate clinical assessment. In the absence of such standards, clinicians can confuse normal anatomical variation with pathology or ignore subtle deviation which the patient might have certain disease.

Moreover, the use of MDCT in paediatric renal evaluation has to be trade off with radiation exposure taking place among children. Although the use of ultrasound is most preferred because of its safety profile, MDCT is used in many cases when a high degree of information about the anatomy is needed like during pre-surgical planning or when the results of ultrasound are inconclusive. The spatial resolution of MDCT is very high leading to a measurement in terms of length, width, thickness and volume of the renal which is very invaluable in determining powerful range of reference.

In conclusion, creation of CT-based pediatric kidney size reference ranges in Pakistani children is a vital progress in the fields of pediatric radiology and nephrology. With proper and population-specific standards about the size of the kidneys, clinicians can more effectively identify and track renal deviations. The study is based on the available international research and fills the vital gap in the regional literature which has provided a base to enable a better approach to diagnostic accuracy and patient care of renal health in children.

LITERATURE REVIEW

The measurement of renal size in pediatrics has long been used as a fundamental aspect of clinical nephrology and radiology since kidney size is intertwined with renal growth, maturation, and pathological diseases. The correct range of the reference has to be revealed to differentiate the normal developmental variation and disease like renal hypoplasia, dysplasia, or chronic kidney disease. In the last 20 years, several imaging modes such as ultrasound, magnetic resonance (MRI) and computed tomography (CT), especially Multidetector Computed Tomography (MDCT) have been employed in determining normative data in kidney size in children. Nevertheless, consistency within populations, procedures in imaging, and measures has posed continuous difficulties in terms of standardizing reference values (Garg et al., 2013; Schmidt et al., 2011).

Ultrasound is the most popular mode of determining kidney size in pediatrics because it is safe, readily available and without ionizing radiation. Some studies have revealed that renal length and anthropometric measure like age, height, weight, and body surface area have had a strong correlation. According to Haugstvedt et al. (2010), the increase in renal length is a predictable outcome of age, but there is a great variance in the outcomes when children of the same ages are compared. Other researchers, such as Rosenbaum et al. (2015), have similar results with body height indicating greater predictive value of renal size compared to age alone, indicating that somatic maturation is a more accurate predictor of renal size than chronological age. The limitations associated with ultrasound despite these advantages are: Operator dependency and the inability to get consistent values with obese and uncooperative pediatric patients.

MRI is an alternative method of renal volumetry with increasing use as a radiation-free method in children. MRI gives high resolution images and gives the opportunity to make good three-dimensional evaluation of kidney volume without exposure to ionizing radiations. A study by Cheong et al. (2014) also showed that MRI-derived renal volume has a strong correlation with body surface area and yielded a better measurement compared to ultrasound. Their high cost, low availability, and the necessity of the use of sedation in young children limit its common clinical application, however. These drawbacks notwithstanding, MRI-based research has helped to develop reference curves of renal growth in children (Sanna-Cherchi et al., 2017).

Computer tomography (CT), and especially MDCT, have an excellent spatial resolution and anatomical details, which is why they are very useful in the measurement of the size of the renal area. The CT imaging provides a chance to effectively measure the length, width, thickness, and even volume of the renal in complicated clinical cases. As shown by Talhar et al. (2017), CT-based renal volume estimations have a very strong correlation with body weight and height and could be regarded as helpful in the determination of normative data. On the same note, a study by Zhang et al. (2019) found that kidney volumetry CT gives more precise and consistent results in relation to ultrasounds especially when there are anatomical anomalies or asymmetry of the kidneys.

Although accurate, the CT is not regularly administered in the development of pediatric reference standards because of the issues of radiation exposure. Nevertheless, retrospective analysis is a good chance to create normative datasets without extra radiation risk in clinically indicated instances of CT scams, which are already in progress. Researchers have highlighted the significance of utilizing available clinic CT to compute population-specific reference ranges in places where norms based on ultrasound might be atypical (Keller et al., 2016).

The problem with validity of the reference ranges of different populations in pediatric renal size measurement is critical. There is renal growth influenced by ethnic, genetic and environmental factors. Indicatively, researchers done on European and East Asian populations have proved a difference in kidney size when compared to South Asian children although this fact has been corrected considering the body size (O'Neill et al., 2012). This brings out the need to come up with region specific reference standards instead of using generalized international charts.

Somatic growth parameters have a significant correlation with renal growth in a pediatric population. The heights of study subjects have been found to be the most consistent predictor of the renal length amongst various studies. Han et al. (2016) mentioned that the length of kidneys is proportional to height between infancy and adolescence. On the same note, Dinkel et al. (2010) discovered that kidney volume is significantly correlated with body surface area, than with age, indicating that in reference models, anthropometric scaling should be used. Such results indicate that the reference range in future must be developed considering several growth indicators as opposed to basing solely on the age classification.

One more significant point that is observed in literature is the asymmetry of the sizes of right and left kidneys. Various reports have documented that the difference between the left and the right kidney is that the left one is a little bigger than the right. This anatomic difference has been explained by the spatial limitations posed by the liver on the right side (Kim et al., 2018). These asymmetries should be taken into account in determining reference ranges because the neglect of physiological differences can result in an incorrect understanding of normal variation as a condition of pathological enlargement or shrinkage.

The fact that chronic kidney disease (CKD) and congenital anomalies of the kidney and the urinary tract (CAKUT) in addition to them have underscored the significance of proper renal size determination. The decrease in size of the kidneys is a frequent initial sign of chronic kidney damage and compensatory hypertrophic responses might point to unilateral impairment. Harambat et al. (2012) report that early detection of renal size abnormalities in CKD children leads to great improvement in prognosis and treatment success. Thus, the appropriate reference standards are critical to timely diagnosis and track the course of diseases.

In developing world countries, such as Pakistan, pediatric renal size reference ranges that are locally derived are an important clinical practice gap. The majority of clinicians use international standards which are not necessarily appropriate to show the peculiarities of the population. This may cause failure in the renal size abnormalities to be classified. Recent regional investigations have tried to fill this gap, having created ultrasound-realized reference charts; nevertheless, very few CT-based normative information exists although more accurate and reproducible (Ali et al., 2020).

The current developments in MDCT technology have enhanced image quality adding low radiation dose and consequently the use of MDCT in clinical population amongst children has become feasible. New CT protocols enable safer imaging with lower doses, without a reduction in the diagnostic accuracy. Smith-Bindman et al. (2012) argue that the strategies of dose optimization have greatly decreased radiation exposure in pediatric CT scans, which can be used in retrospective studies to derive normative data.

In sum, the literature has constantly shown that renal size among children depends on various factors such as age, height, weight, body surface area, ethnicity, among others. Although ultrasound is the means of choice in clinical practice, MRI and CT are more accurate in volumetric evaluation. Nevertheless, no uniform, population-specific CT-based reference ranges are available, especially in the South Asian populations. This gap portrays the necessity of studies like the current one, which focus on determining pediatric norms of kidney size using MDCT in Pakistani children so as to enhance diagnostic accuracy and clinical decision-making.

METHODOLOGY

This research assessed Multidetector Computed Tomography (MDCT) which offered reference ranges of pediatric kidney size in Pakistani children using a retrospective quantitative research design. The retrospective design was deemed the best since it enables use of previously taken CT scan data and no extra radiation can be offered to children who are prone to very high levels and a good anatomical evaluation can be given.

This was done in a tertiary care hospital environment where the pediatric patients are habitually subjected to abdominal MDCT scans due to clinically justified causes. The study population was composed of children aged 0-18 years who had already had abdominal CT images in the period of the study. Scans that had normal renal morphology with no sign of renal pathology, congenital abnormality, tumor, hydronephrosis and chronic kidney disease were only considered in order to generate true normative instance figures.

Radiology records were used to select a total of 300 pediatric patients which were sampled under systematic random sampling method. All eligible CT scans were considered in series with each nth case meeting the inclusion criteria being sampled until the recruitment target number was attained. This was a means to be representative and reduce selection bias.

Data on CT imaging were obtained using Picture Archiving and Communication System (PACS). The scans were all done on a Multidetector CT scanner under the normal abdominal procedures. Axial, coronal and sagittal planes measurements were taken to maintain accuracy and reproducibility. The sizes of kidneys were measured as renal length, renal width and renal thickness. The standard ellipsoid formula was used in calculating renal volume:

- Renal volume = Length Width Thickness/0.523.
- Two independent radiologists did all the measurements and the average of the two was taken to minimize inter-observer variability. Where discrepancy was noted, the scan was again assessed by a third senior radiologist to have an agreement.
- Hospital medical records were used to gather demographic information, such as age, gender, height and weight. The mosteller formula was used to calculate body surface area (BSA):
- BSA = $\sqrt{[(\text{Height} \times \text{Weight}) / 3600]}$
- Study dependent variable was the size of kidneys (length, width, thickness, and volume) whereas the independent variables were age, gender, height, weight, and body surface area.

Statistical Package of social Sciences (SPSS) version 26 was used to analyze the data. Mean, standard deviation, frequency and percentage were used as descriptive statistics to highlight demographic and renal measurement data. Pearson correlation test that falls under the convolutes of inferential statistics were used to determine the association between the kidney size and anthropometric data. Tenets renal diameter were compared between males and females by using independent sample t-tests. ANOVA was used on a single occasion to determine the size of kidneys in relation to the various age groups.

The significant predictors of kidney size in relation to age, height, weight, and body surface area were analyzed using multiple linear regression analysis. A p-value of under 0.05 was taken to be statistically significant.

Data collection was preceded by the institutional ethics review committee providing ethical approval. Because it is a retrospective study, there was no need to have patient consent; but all patient data was strictly kept confidential. No identifiable personal details were made and all information were utilized on academic and research terms only.

This was a well-defined statistically sound methodology that was used to create CT-based pediatric kidney size reference ranges, and it is highly accurate, reproducible, and clinically relevant to Pakistan pediatric population.

DATA ANALYSIS

SPSS version 26 was used to analyze data. The final analysis encompassed 300 CT scans of children. It was analyzed in three phases: descriptive statistics, comparative analysis, correlation analysis and multivariate regression analysis. The p-value of 0.05 was the statistically significant value during the study.

Table 1: Demographic Characteristics of Study Participants (N = 300)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	162	54.0
Gender	Female	138	46.0
Age Group	0–5 years	72	24.0
Age Group	6–10 years	84	28.0
Age Group	11–15 years	78	26.0
Age Group	16–18 years	66	22.0

There was a small difference in representation of males (54) and females (46) in the sample. The age range was also relatively equal with a majority of the samples were represented by those aged 6–10 years (28%). This was allocated to guarantee that all stages in the development of the kidneys were well represented so that comparisons of kidney size between the different age groups were attainable easily.

Table 2: Mean Kidney Dimensions by Side (N = 300)

Kidney Parameter	Mean ± SD
Right Kidney Length (cm)	8.41 ± 1.62
Left Kidney Length (cm)	8.73 ± 1.58
Right Kidney Width (cm)	3.91 ± 0.74
Left Kidney Width (cm)	4.02 ± 0.71
Right Kidney Volume (cm^3)	63.5 ± 18.4
Left Kidney Volume (cm^3)	68.9 ± 19.1

The right kidney was always smaller than the left kidney in all of the parameters measured. This disparity can be explained by the anatomical location and functional compensatory factors, in which the left kidney usually perceives a little adjoining in the space and perfusion with the right kidney.

Table 3: Kidney Size Comparison by Gender

Parameter	Male (Mean ± SD)	Female (Mean ± SD)	p-value
Kidney Length	8.95 ± 1.54	8.12 ± 1.49	0.001
Kidney Volume	70.2 ± 18.9	62.4 ± 17.6	0.002

There were also significant gender differences in kidney size there being higher mean kidney length and volume in males as compared to females. This can be linked to general increases in body size, muscle mass and surface area of body in male children which determines organ development.

Table 4: Kidney Size Across Age Groups

Age Group	Kidney Length (Mean ± SD)	Kidney Volume (Mean ± SD)	p-value
0–5 years	6.21 ± 0.88	35.6 ± 10.2	<0.001
6–10 years	7.89 ± 0.94	55.3 ± 12.7	<0.001
11–15 years	9.12 ± 0.87	74.8 ± 14.6	<0.001

16–18 years	10.31 ± 0.92	92.5 ± 15.3	<0.001

There was a good increment of progressive increase of kidney size with increase in age. The maximum kidney sizes were observed in 16-18 years group. This is a clear sign that age plays a strong role in the growth of the kidney and the growth is somatic during the period of childhood and adolescence.

Correlation Analysis

Pearson correlation was used to establish the correlation that exists between the size of kidneys and anthropometric measures.

Table 5: Correlation Between Kidney Size and Anthropometric Variables

Variable	Kidney Length (r)	Kidney Volume (r)	p-value
Age	0.82	0.85	<0.001
Height	0.79	0.83	<0.001
Weight	0.74	0.78	<0.001
BSA	0.88	0.91	<0.001

There were strong positive correlations between kidney size and all anthropometric variables. The correlation was found to be the strongest with the body surface area (BSA), hence body surface area is the most predictable predictor of the size of kidneys in children populations.

Regression Analysis

To determine independent predictors of kidney volume, multiple linear regression was done.

Table 6: Predictors of Kidney Volume (Multiple Regression Analysis)

Predictor	Beta (β)	t-value	p-value
Age	0.31	4.82	<0.001
Height	0.27	3.94	<0.001
Weight	0.21	3.11	0.002
BSA	0.42	6.53	<0.001

Body surface area (BSA) proved the best predictor of kidney volume, age and then height. The model showed that kidneys sizes are largely dependent on total somatic development and not an individual anthropometric measure.

DISCUSSION

The current paper was seeking to come up with CT-based reference values of pediatric kidney size in Pakistani children as well as identify the significant anthropometric predictors that affected renal sizes. The results showed that there is a progressive growth in the size of kidneys with kidney measurements having a high correlation with anthropometric parameters like height, weight and body surface area (BSA). Of these, BSA turned out to be the most important predictor of kidney volume, and the overall body growth is highly correlated with renal development.

The above kidney size growth rates between age groups are skewed which is in agreement with the known physiological growth curves that have been documented in children with nephrology. Renal growth is also known to coincide with somatic growth especially in the infancy and adolescence during which the physiological development is rapid. The same has been observed in past researches as the renal dimensions have been increasing continuously between infancy and late adolescence as they reflect maturation of renal parenchyma and functional demands.

In the current experiment, the size of kidneys was slightly bigger in males than in females. This gender disparity could be related to differences in the size of the body, muscle endowment, and hormonal effects during development. Such differences based on gender have also been reported by past studies, but some of them also indicate that such differences tend to decrease on adjustment to the body surface area, indicating that somatic growth is a more powerful determinant than sex per se.

There was a slightly larger left kidney compared to the right kidney among all ages. This observation is consistent with anatomical and physiological literature which indicates that the left kidney is usually larger in terms of volume because of spatial positioning and the movements of the veins. The deviation though statistically small, is believed to be clinically significant in radiological evaluation and must be factored when deciphering imaging of children.

The key discovery of this study was that the size of kidney was strongly positively associated with body surface area (BSA), more so than either age, height or weight. This indicates that single variables based on anthropometric measurements are less effective indicators of renal growth than BSA. The same findings have been observed in prior research in which BSA was found to be the most predictable variable of organ size especially among children.

Regression analysis also revealed that the BSA, age and height were key predictors of kidney volume with BSA having the largest standardized beta coefficient. This shows that the development of the kidney is multifactorial yet mainly influenced by the overall body proportionality as opposed to specific growth parameters. Findings have a clinical significance because they provide support to the application of BSA-based reference standards in the practice of pediatric radiology and nephrology.

Multi-detector Computed Tomography (MDCT) was used in this study and renal measurements of dimensions were very precise and reproducible. Compared to ultrasound, MDCT can be used to perform a precise volumetric examination and to minimize the inter-observer variability. Nonetheless, MDCT is not regularly suggested in healthy children screening because of the radiation exposure, though it is accurate. Hence its use in this study was legitimate because scans were retrospectively reviewed because of clinically suggested imaging.

In general, this study has valuable population-specific reference data to offer to Pakistani children. Extant literature demonstrates great interethnic and regional differences in kidney size, and the need to have local reference standards. The current research fills this gap as it reports MDCT-based normative values that have the potential to enhance the accuracy of the diagnoses in children with their kidney issues.

CONCLUSION

The research reached the conclusion that the kidney size of children grows tremendously as they age and is highly dependent on anthropometric factors, especially on body surface area. The kidney size is a little bigger in males than in females, where the size of the left kidney is always bigger than that of the right kidney. Body surface area was found to be the most predictive variable of renal size. This study indicates the necessity of the use of population-specific reference ranges that will ensure correct interpretation of radiology in children. MDCT is a safe imaging method that offers an accurate renal measurement though the radiation is detrimental and its use is minimal based on clinical indication.

RECOMMENDATIONS

1. The development and integration of BSA-based reference charts of pediatric kidney size in Pakistan into clinical radiology practice are advisable.
2. The radiologists ought to pay attention to age, gender and anthropometric parameters in interpretation of pediatric renal imaging.

3. The research needs to be extended with additional multicenter research to determine national level normative data in diverse populations.
4. Further standardization and comparison with MDCT-based results of non-ionizing imaging modalities should be performed to be used in routine clinical practice.
5. Future studies will need longitudinal studies that will observe how the renal growth varies with time as part of the same group.

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