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To Determine the Renal Size in Normal Children by Ultrasonography

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Abstract
Background: *There are numerous advantages of ultrasonography in determining renal size. They include the lack of ionizing radiation exposure, radiographic magnification and*
Osmotic effect of the iodinated contrast material .The examination is real time, tridimensional, independent of organ function and phase of respiration. Previously the kidney size was accurately measured on intra venous urography which had its own disadvantages.
Objective: *To determine the renal size in normal children by ultrasonography and Correlation of renal size with somatic parameters like age, weight, height and body surface area.*
Methodology: *It was a prospective observational study, was done in Niloufer hospital for women and child between 2012 march to 2013 march. Normal children aged 1 month to 12 yrs were included in the study. These children were either healthy siblings of patients attending the out-patient clinics or those visiting well – baby clinics. A Philips real –time mechanical sector scanner of 3.5 – 5 MHZ frequency with electronic calipers was used to measure the length, width and thickness of each kidney with the child placed in a supine oblique position. Child somatic parameters were compared to kidney size.*
Results: *There were 250 children in 16 age groups from 1 month to 12 years of age. The mean renal length increased steadily with age from 4.4 cm at 1 month to 8.7 cm at 12 yrs of age with a standard deviation of 0.5 at 1 month to 0.9 at 12 years of age. The mean renal volume increased from 9.9 ml at 1 month of age to 62.8 ml at 12 yrs of age with a standard deviation of 5.0 at 1 month to 13.9 at 12 years of age. The best correlation was of kidney length with body height and the best correlation was of renal volume with BSA.*
Conclusion: *Renal length as measured by ultrasonography is a simple, practical and reproducible measurement and widely accepted to monitor renal size and growth.*
Key words: *children, kidney size, ultrasonography.*

I. Introduction

The assessment of renal size is an integral part of evaluation of renal diseases for both diagnostic and prognostic purposes. Sonography is a noninvasive modality for measuring renal size. Data on normal renal size are available from western population[1-3]. Indian data regarding renal size and its correlation with other somatic parameters in normal Indian children are based on studies with a small sample size and sparse age distribution [4-9].The present study was undertaken to determine renal size in normal Indian children (1m-12yrs). There are numerous advantages of ultrasonography in determining renal size. They include the lack of ionizing radiation exposure, radiographic magnification and Osmotic effect of the iodinated contrast material.

II. Aims and Objectives

1. To determine the renal size in normal children by ultrasonography
2**.** Correlation of renal size with somatic parameters like age, weight, height and body surface area.

III. Methodology

It was a prospective observational study, was done in Niloufer hospital for women and child between 2012 march to 2013 march. Normal children aged 1 month to 12 yrs were included in the study. These children were either healthy siblings of patients attending the out-patient clinics or those visiting well – baby clinics. Consent was obtained from accompanying parents. Children suffering from any acute or chronic ailment and with genitourinary tract abnormalities were excluded from the study. Age, weight and height were recorded at the time of examination. Infants were weighed on an infant weighing scale and older children on a beam balance. Weights were recorded to the nearest 100 gms. The supine lengths were measured on an infantometer in children below 2 yrs and the standing height was measured on a stadiometer in children above 2 yrs to the nearest 1 mm.

The Body surface area was

Calculated by Mosteller formula: $\sqrt{\frac{\text{Weight (kg) x height (cm)}}{60}}$

A Philips real –time mechanical sector scanner of 3.5 – 5 MHZ frequency with electronic calipers was used to measure the length, width and thickness of each kidney with the child placed in a supine oblique position. The maximum renal length was recorded after repositioning the probe in several angulations. Renal width was measured at renal hilum and thickness was recorded from transverse scans showing the maximum dimension. Length or height of the child was measured to the nearest cm and weight was recorded to the nearest 100gm. Kidney length , width and depth were calculated to the nearest mm. Renal volume was calculated in ml by the formula :Volume = 0.5223 x Length x Width x Depth. The mean length, width and volume of the right and left kidneys were calculated separately for age groups of 1 month, 3 months, 6 months, 9 months, 1 year, and thereafter every year throughout 12 years. Renal Length and Volume were the two variables of renal size considered for correlating with somatic parameters. Coefficients of correlation were derived for each pair of variables. The statistical difference among the groups was determined by t test. Coefficient of correlation was determined by Pearson coefficient of correlation.

IV. Results

262 children (132 males, 130 females), who were apparently healthy underwent ultrasound abdomen. 2 children (1male and 1 female) had renal cysts and 10 children had unilateral hydronephrosis (4males and 6 females). These 12 children were excluded from the study. There were 250 children (123 females and 127 males) in 16 age groups from 1 month to 12 years of age. The number of children within each age group ranged from 9 to 30 with a mean of 19 children. The mean height increased from 50 cm at 1 month to 142 cm at 12 yrs of age with a standard deviation of 2.2 cm at 1 month to 6 cm at 12 years of age. The mean weight increased with age from 2.6 kg at 1 month to 32 kg at 12 yrs of age with standard deviation of 0.3 at 1 month to 4.9 at 12 years of age. The mean body surface area (SD) increased with age from 0.19 m2 at 1 month to 0.82 m2 at 12 yrs of age with a standard deviation of 0.02 at 1 month to 0.05 at 12 years of age. The mean renal length increased steadily with age from 4.4 cm at 1 month to 8.7 cm at 12 yrs of age with a standard deviation of 0.5 at 1 month to 0.9 at 12 years of age. The mean renal volume increased from 9.9 ml at 1 month of age to 62.8 ml at 12 yrs of age with a standard deviation of 5.0 at 1 month to 13.9 at 12 years of age.

Out of the 250 children included in the study, 127 were male and 123 were female. There was no significant difference between the renal lengths of male and female ($p=0.13$). The difference in mean renal lengths between right (6.61cm) and left kidney (6.59 cm) was statistically insignificant ($p= 0.08$). The difference in the mean renal volumes of right kidney (32.75 ml) and left kidney (32.72 ml) was also statistically insignificant ($p = 0.12$). There is a good correlation between age and kidney length ($r = 0.972$), weight and kidney length ($r=0.955$), body surface area and kidney length ($r = 0.940$) and height and kidney length
($r = 0.932$). Correlations between Renal volume and body height($r = 0.983$), Renal volume and body weight($r = 1.023$), Renal volume and BSA ($r = 1.04$). The best correlation was of kidney length with body height and the best correlation was of renal volume with BSA.

Table 1. Age Wise Distribution of Subjects

Age	weight(kg) mean(SD)	height(cm) mean(SD)	BSA(M2) (SD)	Renal Length(Cm) Mean (SD)	Renal Volume(ml) Mean (SD)
1m (n=18)	2.6 (0.3)	50 (2.2)	0.19 (0.02)	4.4 (0.5)	9.9 (5.0)
3m (n=12)	3.7 (0.6)	53.9 (4.4)	0.24 (0.05)	4.7 (0.8)	12.3 (5.8)
6m (n=15)	5.5 (1.0)	62 (4.8)	0.30 (0.06)	5.4 (0.9)	18.1(6.8)
9m (n=20)	7.1 (0.6)	69 (3.9)	0.38 (0.06)	5.6 (0.7)	19.9 (7.0)
1yr(n=30)	8.3 (0.9)	72 (3.0)	0.45 (0.05)	5.7 (0.8)	21.6 (6.5)
2yr (n=19)	9.5 (1.2)	79.5 (7.9)	0.50 (0.06)	6 (0.8)	26 (8.2)
3yr (n=14)	11 (1.3)	89.5 (5.5)	0.55 (0.06)	6.7 (0.6)	31.2 (6.7)
4yr (n=15)	12.7 (0.8)	95.9 (4.9)	0.60 (0.05)	6.8 (0.7)	32 (7.8)
5yr (n=16)	14.2 (1.5)	101 (4.8)	0.65 (0.06)	6.8 (0.9)	33.1 (6.8)
6yr(n=14)	16.3 (2.0)	108 (6.0)	0.70 (0.04)	6.9 (0.8)	34.2 (9.4)
7yr (n=13)	17.8 (1.8)	113 (6.1)	0.75 (0.05)	7.3(0.7)	45.1 (10.5)
8yr (n=14)	20.9 (2.4)	117.2(6.0)	0.82 (0.05)	7.6 (0.8)	50.1 (10.9)
9yr (n=14)	24.5 (2.9)	126 (4.2)	0.88 (0.07)	8 (0.9)	56 (13.9)
10yr(n=12)	26.5 (4.1)	131 (6)	0.94 (0.06)	8.1 (0.8)	58 (14.3)
11yr(n=9)	31.5 (4.5)	139 (5)	1.03 (0.08)	8.6 (0.6)	61 (14.7)
12yr(n=15)	32 (4.9)	142 (6)	1.04 (0.08)	8.7(0.9)	62.8(13.9)

V. Discussion

Before ultrasound was used for measuring renal size, Hodson et al1[10] in 1962, reported the renal size of 393 children based on excretory urography and presented a graph of renal length vs. age. However, the radiographic technique itself yields some variability in the apparent size of the kidney due to differences in centering of the tube and its distance from the patient, phase of respiration, and osmotic effects of iodinated contrast material[11, 12]. Sonography allows measurements that are not subject to the above variables and furthermore provides such information without exposing the patient to ionizing radiation. The potential of renal Sonography in children was outlined by Lyons et al[13] and was expanded by subsequent reports[14, 15]. Sonographic measurement of renal length in 30 children was reported by Tay et al[16], but the data were compared only to excretory urography data, without mention of whether the studies were normal or not, and no renal length or patient age comparison was made. Renal size was conventionally determined on X-rays or urography by measuring the renal length ,distance of the 1st lumbar vertebra (L1) to the 3rd (L3) or 4th lumbar vertebra (L4), and parenchymal thickness .The measurements obtained by these methods were associated with various drawbacks. With the advent of newer modalities of investigations, ultrasound Sonography, computed tomography (CT) and magnetic resonance imaging (MRI) have been effectively used for estimation of renal parameter. The US method that is used to measure kidney volumes is two-dimensional in nature, is subject to operator dependence and uses geometric assumptions about the shape of kidney to estimate kidney volumes. In contrast, CT and MRI can acquire three-dimensional (3D) data and therefore, do not rely on geometric assumptions to estimate organs volumes. In the case of CT, the need for ionizing radiation and potentially nephrotoxic contrast media limits its place as a routine noninvasive imaging method for measuring kidney volumes. Similarly, Magnetic Resonance Imaging (MRI) also has its own limitations in clinical use.

In the present study (n = 250), mean renal length (SD) increased steadily from 4.4 (0.5) cm at 1 month to 8.7 (0.9) cm at 12 yrs of age. In a study done by Otiv et al[17], the mean renal length (SD) increased steadily with age from 4.3 (0.6) cm at 1 month to 8.6 (0.8) cm at 12 years of age. In a study done by Rosenbaum et al[18] (n = 203), mean renal length (SD) increased from 5.28 (0.66) cm at 2 months of age to 10.42 (0.87) cm at 12.5 years of age. Renal length correlated well with most commonly used parameters of overall body size including age, body weight, and body height and body surface area in the present study. The best correlation of renal size was seen with body length and body surface area. Renal volume correlated best with body surface area. In a study done by Rosenbaum et al[18], renal length was measured from normal real-time sonograms of 203 pediatric patients and graphed to provide a “growth chart” of normal renal size vs. age. Sonography was performed on 203 children with a real-time mechanical sector scanner, either a Diasonics Wide-vue using a 3.5, 5, or 7.5 MHz transducer or a Diasonics NeonatalmUnit using a 6 MHz transducer. Mean renal lengths are reported for each year of age. For children older than 1 year, the regression equation is: renal length (cm) = 6.79 + 0.22x age (years). For babies younger than 1 year, the equation is: renal length (cm) = 4.98 + 0.155 x age (months).Safak et al[19] , in 712 healthy school aged children(7-15), observed that there are no significant differences in renal dimensions with respect to sex. The mean right kidney length was shorter than the left kidney length and the difference was significant (P=0.009). Longitudinal dimensions of right and left kidneys showed a statistically significant correlation with the measured body surface area. Although body proportion and rate of general somatic growth are strikingly different between boys and girls, their renal lengths did not display a significant difference in the present study (p 0.13). In the present study , renal length had good correlation with body height (r = 0.932) , body surface area (r 0.940) , body weight (r 0.955) ,and age (r 0.972). This is supported by a study done by Otiv et al[17], which also showed a good correlation of renal length with body height (0.9) and renal length with body surface area (r 0.89). But the best correlation of renal length was with body height (r 0.932) in the present study as compared to Otiv et al, who proved the best correlation of renal length with body surface area (r 0.89).

Gavela et al[20]showed a good correlation between body height and left kidney length (r 0.911) and right kidney length (r 0.921) respectively. The same study also showed good correlation between BSA and left kidney length (r 0.896) and right kidney length (r 0.902) respectively. In the present study, renal length showed good correlation with body weight (r = 0.955). Gavela et al also reported a good correlation between body weight and length of left kidney (r 0.863) and left kidney (r 0.871). Body weight showed the best correlation with right kidney dimension according to venugopal et al[21]. Renal length is closely correlated with age of the child in the present study (r 0.972). This is supported by Gavela et al who showed a close correlation between age and left renal length (r 0.857) and right renal length (r 0.872) respectively. In a study done by Dvries et al[21], the ratio of kidney length to crown-to-heel measurement was made in 20 infants. The ratio ranged from 0.70 to 0.85 with a mean of 0.78. In infants who were either small or large for gestational age the kidney size remained in proportion with the length of the infant. There was no statistically significant difference in the length between the right and left kidneys.

In the present study, the mean renal volume (SD) increased from 9.9 (5.0) ml at 1 month of age to 62.8 (13.9) ml at 12 yrs of age. In the study done by Otiv et al, the mean renal volume (SD) increased from 9.7 (4.4) ml at 1 month to 61 (17) ml at 12 years of age. Kidneys become relatively wider and thicker with age. One possible explanation for this could be the relaxation of the abdominal wall with age, so that the kidneys are squeezed less in older persons. This would also explain the broadening that becomes most pronounced for the right kidney, which has been squeezed more because of the liver. In their study renal length correlated best with body height. Measurements of renal length obtained with the subjects supine were not significantly different from those obtained with the subjects prone. In all age groups, the parenchymal volume of right kidney was significantly smaller than that of the left. An explanation is that the left renal artery is shorter and straighter than the right one[23]and hence increased blood flow in the left artery may result in relatively increased volume. In the present study, the mean renal volume (SD) increased from 9.9 (5.0) ml at 1 month of age to 62.8 (13.9) ml at 12 yrs of age. The difference in the mean renal volumes of right kidney (32.75 ml) and left kidney (32.72 ml) was also statistically insignificant (p 0.12). In the present study, body height correlated well with renal volume (r 0.983). Renal volume also had good correlation with body height in cms (r=0.85) in the study conducted by Otiv et al. In the present study, there was a correlation between renal volume and body weight (r1.023) and there is a correlation between renal volume and body surface area (r 1.04). In a study done by J H Kim et al[24], among 794 Korean children under 18 years of age including a total of 394 boys and 400 girls without renal problems, renal volume showed the strongest significant correlation with patient weight (R2, 0.842 and 0.854 for the right and left kidneys, respectively, $p < 0.001$).In a cross-section study on 116 healthy children by Adibi et al[25], the mean age of the children was 8.4+/-3.4 yrs. The GFR mean was 108+/-30 (ml/minper1.73 m2). GFR correlated to total renal volume (r=0.52, P<0.001), total net volume (r=0.53, P<0.001) and total kidney length (r=0.59, P<0.001). Ultrasonography kidney sizes, especially the kidney length, correlate to GFR in healthy children. Kidney sizes assessment by ultrasonography may play a role in renal function evaluation in children.

Body mass index is one of the widely-used parameters for measuring obesity. There have been several studies that evaluated body surface area and lean body mass as a predictor of renal size in children[26, 27]. However, there are far fewer studies about the relationships between BMI and renal length and volume. Pantoja Zuzuárregui et al[28] 60 suggested that BMI is well-correlated with renal length. In a study done by Kim et al[24], they found much weaker correlations between BMI and renal length or volume compared with that of height and weight. This suggests that BMI might not be a significant confounder in estimating the renal sizes. Hence, in the present study, BMI has not been calculated for the children. In children with growth failure and in under-nourished children, it will be better to correlate the renal length with the body length. Judged by Sonography, the renal length in Indian children was lower by 11-20% as compared to American children with respect to age, probably due to the larger body size of their American counterpart's .In clinical practice, the body height can be quickly recorded to compare the actual renal length with the renal norm. Similarly, since the estimation of renal volume requires measurement of three dimensions of the kidney, the error associated with renal volume increases in geometric proportion. Hence it is simpler to use renal length as a yardstick for comparing renal growth with body growth.

VI. Limitations of the study

Intraobserver variation, the difference in US techniques, patient positioning, and cursor placement can affect the reproducibility of measurements on renal length. There were no evaluations of renal function measurements such as the serum creatinine level or glomerular filtration rate. In the present study, only evaluated sonographically normal kidneys for renal length and volume. However, renal function may be impaired in these morphologically normal kidneys. There have been several studies showing that renal function influences renal size. Due to the small sample size, this study may not represent the population more closely.

VII. Conclusion

This study provides values of renal length (mean + SD) in normal children. The renal size norms developed by this study provide normal kidney length range for children according to age and body size. The best correlation was of kidney length with body height and the best correlation was of renal volume with BSA. Renal length as measured by ultrasonography is a simple, practical and reproducible measurement and widely accepted to monitor renal size and growth. A growing kidney in a child is a healthy kidney, whereas a kidney static in size over time may be an early indicator of chronic kidney disease.

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