Normal Sonographic Dimensions for Liver, Spleen and Kidneys in healthy South West Nigerian Children-A pilot study

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Abstract

Ultrasonographic measurement of abdominal organ dimensions in children of all ages is utilized in the monitoring of abdominal organ growth pattern, diagnosis and follow-up of patients with a variety of diseases. Base line reference values are necessary to determine abdominal organ growth and the degree of deviation from the normal in pathological states. These values are well established in the developed countries but local reference levels are sparse in this environment.

This is a descriptive prospective pilot study done at Ibadan, Nigeria. One hundred and twenty-nine clinically healthy nursery and primary school children, aged between 3 and 10 years consisting of 74 females and 55 males were recruited into the study. Consent was sought from the school authorities and more importantly from the parents/care givers through letters written through the school authorities. Those pupils whose parents/care givers gave consent were included in the study. The age of each child was documented in months. Height was measured in meters using a measuring tape with child standing against a vertical wall. Weight was also measured using a ZT standing weighing scale. Each child underwent abdominal ultrasound evaluation and measurement of liver, spleen and renal diameters. These parameters were recorded on a prepared data sheet.

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The mean length, width, antero-posterior diameters and volume of the right kidney in males were 7.52cm ±0.95, 3.89cm±0.60, 3.89cm±0.48 and 13.56cm^3±4.73 respectively, while the diameters in females were 7.28cm±0.84, 3.70cm±0.54, 3.95cm±0.54 and 13.98cm^3±4.82 respectively. In the left kidney, in males these parameters were 7.97cm±0.87, 3.78cm ±0.61 and 3.84cm±0.50 and 14.83cm^3±4.67 respectively, while the diameters and volume in females were 7.75cm±0.83, 3.66cm±0.53, 3.90±0.49 and 14.99cm^3±4.44 respectively. The gender difference in renal volumes bilaterally was in favor of females but not statistically significant on either the right (p= 0.530) or the left (p=0.689) kidney. The volumes of both kidneys in both sexes showed positive correlation with their heights. The overall median splenic size was 8.35cm with an interquartile range of 1.70. The mean splenic size in females was 9.14cm ± 8.79, while the mean in males was 8.49cm ±1.17. The overall median liver size was 11.0cm with an interquartile range of 1.30. The mean liver span was greater in males (12.78cm ± 13.7) than in females (10.62 ± 1.1) p=0.074. Also, the liver span, weight and height were positively correlated; with correlation coefficients of 0.037 and 0.013 respectively (p=0.68 and p=0.89).

In this study, normal mean dimensions of the liver and spleen are greater in males than in females. Height, weight and age are poor predictors of renal volume with an adjusted R^2 of 0.076 for the right kidney and 0.096 for the left kidney. However, height alone was consistently statistically significant [p=0.000] in the right kidney. Height, weight and age in months and gender are very poor predictors of splenic and hepatic span with adjusted R^2 of 0.003 and R^2 of 0.001 respectively. This pilot study establishes a normogram for liver, spleen and kidneys size in pediatric age group in Nigeria.

Keywords: normogram Kidneys, Liver, Spleen, Ultrasound, abdominal organs

Introduction

Measurement of abdominal organ diameters in children of all ages is performed to evaluate the growth pattern of abdominal organs[1], and the diagnosis and follow-up of patients with a variety of diseases[2]. An observed increase or decrease in organ size may be associated with specific disease processes. Correlation of measured normal organ diameters, the derived organ volumes and ratios with body parameters of physical growth in children such as height and weight provides reference values. These may serve as baseline to determine the degree of deviation from the normal in pathological states[3]. Radiological modalities that may be used to measure the dimensions and volume of the abdominal organs include Computed Tomography (CT), Magnetic resonance imaging (MRI) and Ultrasonography (US)[1]. The high cost of CT and MRI examination and the high dose of ionizing radiation in CT have made these modalities not so appealing in the study of normal reference values in children. However medical ultrasound is a simple and reliable imaging modality for the assessment and measurement of abdominal viscera[2]. It is affordable, widely available and free of ionizing radiation[3]. Also, ultrasound measurements of distance, as well as 3-dimensional volume measurements are reportedly sufficiently accurate for use in clinical practice[4].

Size anomaly involving abdominal organs such as the liver, spleen or kidneys may be associated with a broad range of disease processes which vary greatly with patient's age[5]. Indeed, an enlarged or shrunken liver, kidney or spleen in children may be suggestive of specific focal or systemic disease process. In our environment, a large number of pathologic entities can affect splenic size in children, such as splenic enlargement in association with malaria infestation (tropical splenomegaly syndrome-TSS)[6]. Clinical examination is often far from accurate in determining small changes in splenic size[7]. Hepatomegaly is a frequent clinical finding in children, and may be caused by intrinsic liver disease or by a variety of systemic disorders[8]. Also, a shrunken liver may result from chronic liver disease following Hepatitis [10]B infection[9]. Knowledge of normal splenic or liver size in relation to age and other biometric parameters of physical growth is of paramount importance in the determination of hepatomegaly or splenomegaly which may co-exist in children. Renal size is an important parameter in the assessment of children with renal disease[10].The kidneys continue to grow in size after birth and reaches near adult size of 10cm by 12 years of age[11]. Decrease in renal size may be associated with chronic renal disease, while an increased renal size may occur in acute kidney injury[10]. Also, there is clinical value in comparing the sizes of the two kidneys as it provides a means of studying the natural history of certain renal diseases[10]. For example, unilateral disease in a child may result in an ipsilateral shrunken kidney and contralateral renal hypertrophy. Also, bilateral renal enlargement may be noted in polycystic disease and some lipid storage disorders. Documented measurement of renal length and volume has been reported in the literature to be correlated with patient's height and weight[12,13]. Age related normograms are generally used to interpret normal renal, liver and spleen sizes[14]. However, many normograms are based on healthy western population, and may not reliably apply to Nigerian children. In order to interpret organ size in disease states it is necessary to have normal reference values for Nigerian children in relation to their age, gender, height and weight.

This pilot study aims to document ultrasound measured normal diameters of kidneys, liver and spleen in healthy Nigerian children of various ages, and to correlate organ diameters with age and gender, and anthropometric measures such as height and weight.

Materials and Methods

This descriptive prospective pilot study was done at Ibadan, Nigeria between July 2010 and December 2011. Ethical approval for this study was obtained from the UCH/UI Ethical Committee. One hundred and twenty-nine clinically healthy nursery and primary school children, aged between 3 and 10 years, 74 girls and 55 boys were recruited into the study. Consent was obtained from parents and authorities of the selected nursery and primary school. Convenience sampling method was adopted. Consecutive recruitment of subjects was done with a view to achieving a fairly even spread in terms of age and gender. Children with a history or symptomatology suggestive of chronic ill-health, those deemed clinically unhealthy or uncooperative were excluded from the study. Also

excluded were children who did not have normal growth curves, i.e. not within the 3rd to 97th percentile.

The age of each child was documented in months. Height was measured in meters using a measuring tape with child standing against a vertical wall. Weight was also measured using a ZT standing weighing scale. Each child then underwent abdominal ultrasound evaluation and measurement of liver, spleen and renal dimensions. All measured organs were sonographically normal. Ultrasound examination was done using a portable Micromax Sonosite Inc. Bothhell, WA, USA ultrasound scanner with a 3.5–5MHz convex transducer. Subjects had neither preparation nor sedation.

Measurement of the liver, spleen and kidneys were performed in all subjects (129). The subject were in supine position, longitudinal dimensions of the liver were obtained in the mid-clavicular line with simultaneous demonstration of the right kidney. In this plane the upper margin of the liver was defined as the uppermost edge under the dome of the diaphragm, whereas the lower margin was defined as the lowermost edge of the lobe[3]. Longitudinal dimension in the coronal plane was obtained with the subject in the supine or slightly right decubitus position. Longitudinal size measurement was performed between the most supero-medial and the most infero-lateral aspect of the spleen[3]. Longitudinal (LS), transverse (TS) and antero-posterior (AP) diameters were obtained in the sagittal and in the coronal planes passing through the renal hilum with subject in the supine or slightly right or left lateral decubitus positions.

To determine reproducibility, the measurement of each organ was performed three times and the mean of the values was recorded. Renal volume was calculated for each kidney using the Ellipsoid formula - LS x TS x AP x $\pi/6$ (0.524).

The sex, age, height and weight were correlated with the diameters of the organs. All measurements were plotted as a function of age in months, body weight and height. The mean, median, minimum and maximum values and standard deviation for the measurements were also calculated (SPSS Version 17 for Windows). Associations between categorical variables were explored with the Chi- Square test, while numeric variables were compared with the Student T- test. Associations were deemed significant if p-value <0.05.

Results

A total of 129 children were scanned comprising 55 males (42%) and 74 females (56%). The ages of the children ranged from 36 to 120 months. The mean age for the males was 76.19 months ± 27.14 while the mean age for females was 71.68±24.28 months. The weight and height range in both sexes combined was 11-32kg and 82-137cm respectively. Males were slightly taller (Mean=113.05cm±13.13) than females (Mean= 111.05cm ± 13.61). The males were also heavier (Mean=20.89kg ±5.38), than the females (Mean= 18.69kg±4.68).

Renal Measurements:

As seen in Table 1, the mean length, width and antero-posterior diameter of the right kidney was 7.38cm±0.89, 3.79cm ± 0.57 and 3.93cm ± 0.51 respectively. The minimum value of the right renal volume is 3.80cm^3 with a range of 24.73cm^3. Also, the mean length, width and antero-posterior diameter of the left kidney was 7.85cm±0.85, 3.71cm±0.56 and 3.87cm±0.49 respectively. The minimum value of the left renal volume was 6.32cm3 with a range of 19.79 cm^3.

Table 1. The length, width and antero-posterior dimensions of the kidneys

	Right kidney [cm]			Left kidney [cm]		
	Length	Width	AP	Length	Width	AP
Min-max	4.67 9.50	2.12 5.27	4.67 9.50	5.78 10.00	2.64 5.16	4.67 9.50
Mean SD	7.38 ±0.89	3.79 ±0.57	3.93 ±0.51	7.85 ±0.85	3.71 ±0.56	3.87 ±0.49

Mean length, width and antero-posterior diameters of the right kidney in males were 7.52cm ±0.95, 3.89cm±0.60 and 3.89cm±0.48 respectively, while the diameters in females were 7.28cm±0.84, 3.70cm±0.54 and 3.95cm±0.54 respectively. Table 1. The mean right renal volume measurement was 13.98cm^3±4.82 in females, and 13.56cm^3±4.73 in males.

The mean length, width and antero-posterior dimensions of the left kidney in males were 7.97cm±0.87, 3.78cm ±0.61 and 3.84cm±0.50 respectively, while the diameters in females were

7.75cm±0.83, 3.66cm±0.53 and 3.90±0.49 respectively. The mean left renal volume was slightly smaller in males 14.83cm3±4.67 than in females 14.99cm^3±4.44. The gender difference in renal volume bilaterally was in favor of females but not statistically significant for the right kidney (p= 0.530) and left kidney (p=0.689) respectively as seen in figure 1.

Figure 1. *Box Plot showing the distribution of kidney volumes by side and gender*

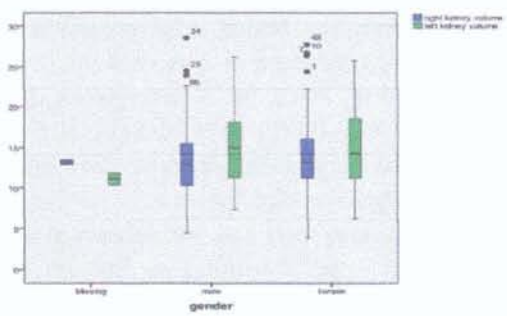
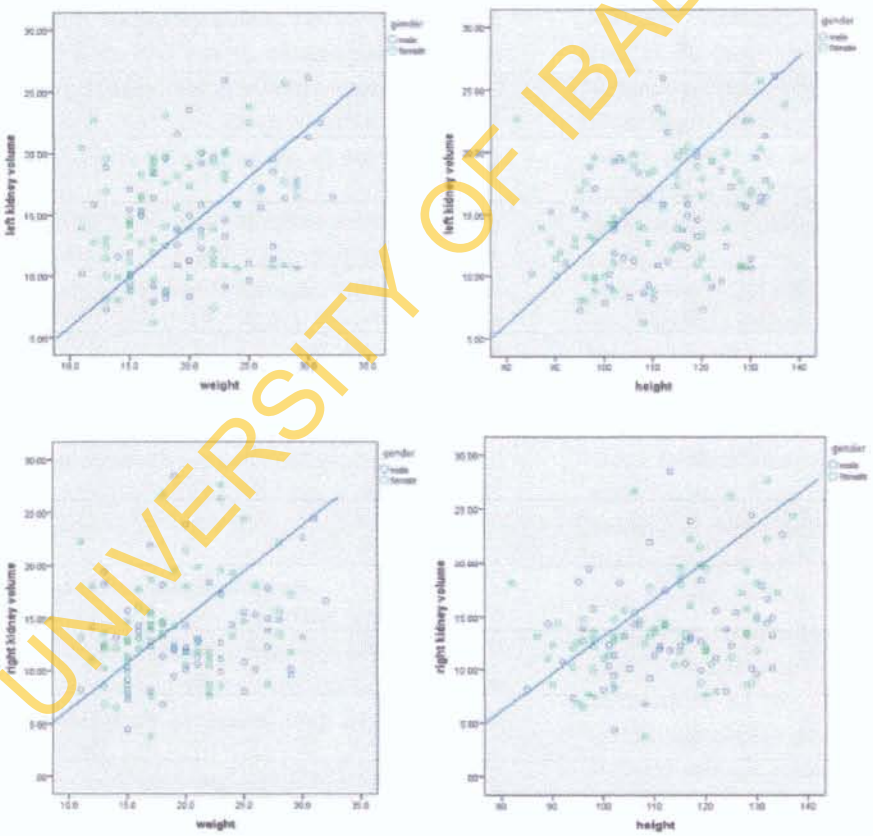


Figure 2. *Scatter Plots showing relationship between kidney volumes by gender, side, weight and height in the study population.*

The volume of the kidneys in both genders were positively but weakly correlated with weight with a correlation coefficient of 0.215 for the right kidney (p=0.14) and correlation coefficient of 0.291 for the left kidney (p =0.001) –statistically significant. The volume of the kidneys in both genders were also positively but weakly correlated with height with a correlation coefficient of 0.306 for the right kidney (p<0.000) and correlation coefficient of 0.329 for the left kidney (p <0.000) –Both statistically significant.

The volumes of the kidneys in males and females separately showed positive correlation with their height and weight. For males, the correlation coefficient between the right kidney volume and weight was 0.190 (p=0.164) while the correlation coefficient between the right renal volume and height was 0.250 (p=0.065). Also, the correlation coefficient between the left kidney volume and weight was 0.352 (p=0.008 statistically significant) and the correlation coefficient between the left kidney volume and height was 0.360 (p=0.007 statistically significant).
On the other hand for females, the correlation



coefficient between the right kidney volume and weight was 0.271 (p=0.020) while the correlation coefficient between the right renal volume and height was 0.330 (p=0.004). Also, the correlation coefficient between the left kidney volume and weight was 0.241 (p=0.040) while the correlation coefficient between the left kidney volume and height was 0.327 (p=0.005). These correlations were statistically significant in females for both kidneys. Figure 2.

Linear and Multiple Regression Analysis

In males, weight, height and age in months combined are very poor predictors of renal volume with an adjusted R^2 of 0.008 (p=0.977), 0.005 (p=0.282) and -0.007 (p=0.537) (95% CI all span 0) respectively for the right kidney; all not statistically significant. For the left kidney, weight, height and age in months are also poor predictors of renal volume with an adjusted R^2 of 0.102 (p=0.371), 0.085 (p=0.316) and 0.118 (p=0.098) (95% CI all span 0), also not statistically significant.

In females, weight, height and age in months combined are very poor predictors of renal volume with an adjusted R^2 of 0.051 (p=0.350), 0.101 (p=0.109) and 0.089 (p=0.738) (95% CI all span 0) respectively for the left kidney. For the right kidney, weight, height and age in months are also poor predictors of renal volume with an adjusted R^2 of 0.055 (p=0.168), 0.129 (p=0.119) and 0.132 (p=0.279) (95% CI all span 0), all not statistically significant.

Weight, height and age in months combined are very poor predictors of overall right renal volume in the entire study population (irrespective of gender) with R^2 of 0.033 (p=0.218), 0.083 (p=0.054), 0.076 (p=0.709) respectively. Also for the overall left kidney volume, weight, height and age in months combined are very poor predictors in the entire study population (irrespective of gender) with R^2 of 0.073 (p=0.959), 0.087 (p=0.670), 0.096 (p=0.141) respectively.

Spleen and liver measurements.

The mean splenic size in females was 9.14cm ± 8.79, while the mean in males was 8.49cm ± 1.17. The overall median splenic size was 8.35cm for the study participants combined with an interquartile range of 1.70.

The mean liver span was greater in males (12.78cm ± 13.7) than in females (10.62cm ± 1.1). The mean difference is 2.15cm with a 95 % CI of (0.97-5.28) p=0.074. However, the overall median liver size was 11.0cm in both genders combined with an interquartile range of 1.30.

The liver span, weight and height were positively correlated; with correlation coefficients of 0.515 and 0.056 respectively (p<0.000). The Splenic span was also positively correlated with weight and height; with correlation coefficients of 0.355 and 0.305 respectively (p<0.000). Weight, height and age in months and gender combined are poor predictors of splenic sizes with adjusted R^2 of 0.000 (p=1.000), -0.004 (p= 0.723), -0.012 (p=0.855), -0.017 (p=0.522) respectively. Weight, height and age in months and gender combined are also poor predictors of hepatic sizes with adjusted R^2 of -0.007 (p=0.637), -0.014 (p=0.422), 0.000 (p=0.119), 0.003 (p=0.240) respectively.

Discussion

In Nigerian health institutions, ultrasound is commonly used for evaluating abdominal viscera in children. It offers numerous advantages due to its simplicity, reliability, availability, and non-use of ionizing radiation[3]. Also, the modality is real time, tri-dimensional and independent of organ function[16]. Recognition of pathologic changes in the size of the liver, spleen and kidneys in children depends on knowledge of the normal size range of these organs for the child's age. In practice, one or more diameters of an abdominal viscera is measured as part of routine abdominal sonographic assessment in children to determine variations from normal[3].

In this study, the mean right and left renal volume was higher in girls than in boys. This was however not statistically significant (t- test, p>0.05 (Right kidney p= 0.530 and left kidney p=0.689) bilaterally), suggesting that sex is not a determining factor for renal size in children, and is in agreement with findings from previous studies [3,17,18,19] Our study also shows positive correlation between the measured right and left renal volume with height and weight in both sexes, though statistically significant bilaterally only in girls. Otiv et al (2012) [20] in their study of ultrasound measured renal dimensions among Indian children, reported a strong correlation of renal size and volume with various somatic parameters, the best correlation was between renal length and body height. Also,

Dinkel et al [18] in 1985 studied renal dimensions measured using ultrasound and reported strong correlation between renal volume and body weight, as well as renal length and body height in both boys and girls. Regarding the non-statistically significant positive correlation of renal volume with somatic parameters for boys in our study, a larger sample size in a future study may be needed to make a definitive statement.

The conventional method of recording hepatic and splenic size by clinical examination has been reported to lack accuracy and reliability[21, 22]; hence the recourse to ultrasound measurement .[3, 22] This study's mean splenic and liver diameters are both greater in males than in females, and the liver span also positively correlates with body weight and height. These findings agree with observations by Dhingra et al[21], they studied liver and splenic dimensions in Indian children aged between 1 month and 12 years. They adopted measurement parameters for both organs similar to our study, and their values are slightly less than the values obtained in our work. However, their mean liver and splenic diameters were larger for males compared to females as was observed in our study. They also reported statistically significant correlation between the liver and spleen with body height and weight. Also, Rosenberg et al[22] adopted a one-step method for sonographic coronal measurement of the normal spleen in American children similar to our measurement technique. They reported slightly greater mean values for boys than girls. Also, splenic length correlated with age, height and weight. Safak et al (2005)[16] studied organ dimensions using a fairly large sample size (712 Turkish children 7-15 years of age) and reported good correlation between body weight and splenic and liver dimensions. However, there was no statistically significant difference in organ size by gender, an observation that may be explained by racial mix and peculiarities of the sample population.

Conclusion:

In healthy Nigerian children, normal mean dimensions of the liver and spleen are greater in males than females. However, there is no statistically significant difference in renal volume by gender. Liver dimensions in both genders and renal volume in females positively correlate with body height and weight. This study has paved way for a more comprehensive study with a large sample size and a broader age range in order to establish a normogram for abdominal organ sizes in pediatric age group in Nigeria.

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Competing interests

Authors declared that no competing interests exist.

Authors' Contributions

The research was designed by OMA. AAJ and OMA performed the Doppler ultrasound studies and with EU carried out the data collection, ATA did the data analysis and interpretation, EU, ATA and AAJ wrote the manuscript. OMA proof read the manuscript. All authors read and approved the final manuscript.

References:

1. Kim JH, Kim MJ, Lim SH, Kim J, Lee MJ. Length and volume of morphologically normal kidneys in Korean Children: ultrasound measurement and estimation using body size. Korean J Radiol. 2013; 14:677-682.

2. Gilja OH, Hausken T, Berstad A, Odegaard S. Measurement of organ volume by ultrasonography. Proc Inst Mech Eng H. 1999; 213:247-259.

3. Konuş OL, Ozdemir A, Akkaya A, Erbaş G, Celik H, Işik S. Normal liver, spleen, and kidney dimensions in neonates, infants, and children: evaluation with sonography. AJR Am J Roentgenol. 1998; 171: 1693-1698.

4. Riccabona M, Nelson TR, Pretorius DH. Three-dimensional ultrasound: accuracy of distance and volume measurements. Ultrasound Obstet Gynaecol.1996; 7: 429-434.

5. Eldridge, D. L., *Newton, D. A. (2008). Organomegaly. In R. M. *Perkin, J. D. Swift, D. A. *Newton & N. G. Anas (Eds.),

Pediatric hospital medicine: Textbook of inpatient management (2nd ed., pp. 114-116). Philadelphia, PA: Wolters Kluwer Health/Lippincott, Williams & Wilkins.

6. Ajao OG. Enlarged spleen syndrome. J.Natl Med Assoc. 1980; 72: 323-325.

7. Megremis SD, Vlachonikolis IG, Tsilimigaki AM. Spleen length in childhood with US: normal values based on age, sex, and somatometric parameters. Radiology. 2004; 231: 129-134.

8. Rocha S.M.S., Ferrer A.P.S., Oliveira R.S., Widman A., Chammas M.C., Oliveira A.N. et al. Sonographic determination of liver size in healthy newborns, infants and children under 7 years of age. Radiol Bras [online]. 2009;42(1):7-13. ISSN 0100-3984. http://dx.doi.org/10.1590/S0100-39842009000100004.

9. Hanif M, Raza J, Qureshi H, Issani Z. Etiology of chronic liver disease in children. J Pak Med Assoc. 2004;54:119-122.

10. Kanitkar M. Kidney size – what is normal? Indian Pediatr. 2012 49:523.

11. Davis ID, Abner ED. Glomerular disease. In: Nelson Textbook of Pediatrics. 18th ed. Philadelphia: Saunders, 2007; 2163.

12. Pantoja Zuzuárregui JR, Mallios R, Murphy J. The effect of obesity on kidney length in a healthy pediatric population. Pediatr Nephrol. 2009; 24:2023-2027.

13. Glodny B, Unterholzner V, Taferner B, Hofmann KJ, Rehder P, Strasak A, et al. Normal kidney size and its influencing factors- a 64-slice MDCT study of 1.040 asymptomatic patients. BMC Urol. 2009; 9:19.

14. Srivastava RN, Bagga A. Pediatric Nephrology. 5th ed. New Delhi. Jaypee Brothers; 2011,547.

15. Bakker J, Olree M, Kaatee R, de Lange EE, Moons KG, Beutler JJ, et al. Renal volume measurements: accuracy and repeatability of US compared with that of MR imaging. Radiology. 1999; 211:623-628.

16. Safak AA, Simsek E, Bahcebasi T. Sonographic assessments of the normal limits and percentile curves of live, spleen, and kidney dimensions in healthy school-aged children. J Ultrasound Med. 2005; 24:1359-1364.

17. Dremsek PA, Kritscher H, Böhm G, Hochberger O. Kidney dimensions in ultrasound compared to somatometric parameters in normal children. Pediatr Radiol. 1987; 17: 285-290.

18. Dinkel E, Ertel M, Dittrich M, Peters H, Berres M, Schulte-Wissermann H. Kidney size in childhood. Sonographic growth charts for kidney length and volume. Pediatr Radiol 1985; 15: 38-43.

19. Zerin JM1, Blane CE. Sonographic assessment of renal length in children: a reappraisal. Pediatr Radiol. 1994; 24: 101-106.

20. Otiv A, Mehta K, Ali U, Nadkarni M. Sonographic measurement of renal size in normal Indian children. Indian Pediatr. 2012; 49:533-536.

21. Dhingra B1, Sharma S, Mishra D, Kumari R, Pandey RM, Aggarwal S. Normal values of liver and spleen size by ultrasonography in Indian children. Indian Pediatr. 2010; 47: 487-492.

22. Rosenberg K.H., Markowitz R., Kolberg H., Park C., Hubbard A., Bellah R.D. Normal splenic size in infants and children: Sonographic measurements. AJR Am J Roentgenol. 1991; 157:119-121.