DOI: 103126/JNPS.V4113

Original Article

Kidney size in Children of Post-Weaning age: Does Nutrition have an Effect?

***Shatanik Sarkar[1], Chaitali Patra[2], Debasree Guha[1], Malay Kumar Dasgupta[3], Santanu Das[4]**

[1]Department of Paediatrics, RG Kar Medical College and Hospital, Khudiram Bose Sarani, Bidhan Sarani, Shyam Bazar, Kolkata, West Bengal 700004, India.
[2]Tapan Sinha Memorial Hospital, Mahanayak Uttamkumar Sarani, Ashok Nagar, Tollygunge, Kolkata, West Bengal 700040, India.
[3] Professor and Head, Department of Paediatrics, KPC Medical College and Hospital, Raja Subodh Chandra Mallick Rd, Jadavpur, Kolkata, West Bengal 700032, India.
[4]Professor, Department of Radiology, RG Kar Medical College and Hospital, Khudiram Bose Sarani, Bidhan Sarani, Shyam Bazar, Kolkata, West Bengal 700004, India.

Article History
Received On : May 23, 2021
Accepted On : May 12, 2022

Funding sources: None

Conflict of Interest: None

Keywords:
Anthropometry; malnutrition; relative renal volume; ultrasound

Online Access

DOI: https://doi.org/10.3126/jnps.v42i1.37245

***Corresponding Author**

Shatanik Sarkar
Assistant Professor,
Department of Paediatrics,
RG Kar Medical College and Hospital,
Khudiram Bose Sarani, Bidhan Sarani,
Shyam Bazar, Kolkata, West Bengal, India
Email: baselinegame@gmail.com

Abstract

Introduction: This study was undertaken to evaluate the effect of nutrition on kidney size and to determine the correlation between renal parameters and different anthropometric parameters.

Methods: This hospital-based descriptive observational study has been done in a tertiary care centre of Kolkata, West Bengal, India. Fifty malnourished children & 50 healthy children (Controls) within the age group of six months to five years were included in the study. Anthropometric parameters (e.g. weight, height, mid-arm circumference, skinfold thickness etc.) were measured manually and bilateral kidney sizes were measured by ultrasound.

Results: Malnourished children had significantly lower weight, mid arm circumference, skinfold thickness, body mass index and body surface area [$p < 0.001$], but the difference in height / length was not significant ($p = 0.074$). The length, width, depth and volume of both left and right kidneys and relative renal volume were significantly lower in the malnourished children ($p < 0.001$). But, the same significance has not been found with kidney width, thickness or volume.

Conclusions: Malnutrition adversely affects kidney growth in children of post-weaning age.

Introduction

Malnutrition is one of the most prevalent health issues, involving hundreds of millions of children all over the world, and particularly in the developing countries.[1] Growth retardation following malnutrition generally affects children of post-weaning age, usually as a result of dietary deficiency of protein or calorie or both.[2] Renal growth is thought to run in parallel to somatic growth, but this is overly simplistic and currently unsubstantiated. But, one of the most important factors identified to be responsible in the growth of the kidneys is the nutritional status of the child.[3]

Kidney size is an important parameter used in the evaluation of renal growth in children, and ultrasonography (USG) has evolved as a non-invasive, reliable and relatively inexpensive method for the assessment of renal size.[1] Though kidney size is mostly described by its length, due to the inherent variability in shape among different individuals, three-dimensional measurements, i.e. total volume of renal tissue, may be a more precise description of kidney size.[4]

Previously, studies have been done to compare kidney sizes in low birth weight children[4] and in children with neuropathic bladder due to meningomyelocoele[5] with that of the normal controls. Kidney growth was also evaluated in formula-fed versus breast-fed healthy infants[6] and in healthy 10 year old children, lean body mass was found to be the strongest predictor of renal volume.[7] The effect of malnutrition in diminishing kidney size in children has been shown in a study from Turkey.[1] However, kidney sizes have not been studied sufficiently in Indian children with malnutrition. The present study is therefore intended to measure and compare kidney sizes of children with malnutrition between six months to five years with those of healthy controls of the same age.

Methods

This hospital- based descriptive observational study with a comparison group was carried out in the Department of Paediatric Medicine in a tertiary care hospital, Kolkata, India between June 2016 to May 2017. After getting Institutional Ethical approval and informed consent from the parents, 50 malnourished children and 50 healthy children (Controls) within the age group of six months to five years, attending the OPD or admitted in the hospital were included. Malnourished children were selected randomly when found to be suitable for inclusion. Children in control group were selected after age- matching with the cases. Children having weight for age less than or = 80% of the expected were included in the malnourished group, whereas those with > 80% of the expected weight for age were included in the control group. Malnourished children were further subdivided into Grade I (Weight for age 71 – 80% of expected), Grade II (Weight for age 61 – 70% of expected), Grade III (Weight for age 51 – 60% of expected) and Grade IV (Weight for age < 50% of expected) malnutrition according to the IAP classification of malnutrition.[8]

Children, who were born either premature (< 37 wks) or post-mature (> 42 wks) and / or small for gestational age (SGA) or large for gestational age (LGA) were excluded from the study. Also the children having congenital anomalies and disorders of the kidney and urinary tract, chronic diseases as tuberculosis, AIDS etc. were excluded.

Proper history and anthropometric measurements were recorded for all the children included in the study as per the pre-designed proforma. Weight was measured by a standard weighing machine, and height (upright; > 2 years) or length (recumbent; < 2 years) by stadiometer or infantometer respectively. BMI was used as a measure of weight for height and was calculated by the formula BMI (Kg / m^2) = Weight (Kg) / [Height (m)]^2. Body surface area [BSA] was determined using the Du Bois & Du Bois formula,[9] which is BSA (m^2) = 0.007184 x [Weight (kg)]$^{0.425}$ x [Height (cm)]$^{0.725}$. Mid-arm circumference [MAC] was measured in the left arm with the help of a standard measuring tape, at the mid-point between tip of acromion & tip of olecranon. Body fatness was estimated by measuring triceps skinfold thickness using a skinfold caliper at the same point as MAC.[10] All children were subjected to ultrasound examination to determine their kidney sizes. If any congenital or anatomical abnormalities were found during USG examination, they were excluded. All the measurements were taken by the same radiologist (Dr. SD) at the same device (L & T Medical, NEC – Accusync 500), using the 2-5 MHz probe for the older children and 5 - 14 MHz probe for the younger ones. The kidneys were identified in the sagittal plane along their longitudinal axis. Measurements of the largest length, width and depth at the hilar level were taken.[11] Kidney volume was calculated in cm^3 using the equation of an ellipsoid, i.e. Volume (cm^3) = Length (cm) x Width (cm) x Depth / Thickness (cm) x 0.523.[12] Relative Renal Volume (RRV) was calculated as RRV (cm^3/kg) = [Lt. Kidney vol. (cm^3) + Rt. Kidney vol. (cm^3)] / Body Wt. (kg).

All the data were collected, compiled and subjected to statistical analysis with the help of SPSS software (Version 17.0; IBM). Microsoft Word and Excel 2007 were used to generate the tables, graphs etc. Results were expressed as mean ± standard deviation for continuous variables and as number (%) for categorical data. Differences between children of the malnourished group and control group were tested with Chi square test (Categorical variables) and Student's t test (Continuous variables). One way ANOVA test with Post Hoc Analysis was used to study the differences in kidney parameters between different grades of malnutrition. Differences between boys and girls and various parameters of left and right kidney were also determined by Student's t test. Pearson's correlation co-efficient was used to determine correlations between different anthropometric and renal variables. Multiple linear regression analysis was performed, when several parameters correlated with a single dependent variable. Significance was assessed at the level of 0.05 (5%).

Results

Among the 100 children included in the study, the mean age of the malnourished group was 27.56 ± 17.49 months and of the control group was 28.06 ± 16.91 months. Both the groups of children matched according to their age, sex distribution and socioeconomic status (p value > 0.05) [Table 1]. But, mean PCI (Per capita income) of the control group (1402.54 ± 923.07) was significantly greater than the malnourished group (920.70 ± 569.29) with a p value of 0.002 (t = -3.142, df = 98).

Malnourished children had significantly lower weight, mid arm circumference (MAC), skinfold thickness (SFT), body mass index (BMI) and body surface area (BSA) [p < 0.001], but did not differ significantly with regard to their height / length (p value = 0.074), though mean height was more in children of the control group (85.38 ± 13.66 cm vs 80.36 ± 14.15 cm in malnourished group) [Table 1].

Table 1. Comparison of different demographic and anthropometric parameters between malnourished and control group

Parameters	Malnourished (N = 50)	Control (N = 50)	Significance
	17.49 ± 27.56	16.91 ± 28.06	t = (-) 0.145, p = 0.885, df = 98
Sex (Male : Female)	27:23	24:26	X^2 = 0.360, p = 0.548, df = 1
Weight (kg)	2.74 ± 7.84	2.86 ± 11.28	t = (-)6.134, p < 0.001, df = 98
Height (cm)/Length (cm)	14.15 ± 80.36	13.66 ± 85.38	t = (-)1.805, p = 0.074, df = 98
MAC (cm)	1.76 ± 12.18	1.20 ± 14.21	t = (-)6.757, p < 0.001, df = 98
SFT (mm)	2.43 ± 9.99	1.98 ± 12.82	t = (-)6.376, p < 0.001, df = 98
BMI (Kg/m^2)	1.60 ± 11.90	1.62 ± 15.46	t = (-)11.03, p < 0.001, df = 98
BSA (m^2)	0.11 ± 0.41	0.11 ± 0.51	t = (-)4.06, p < 0.001, df = 98

The length, width, depth and volume of both left and right kidneys were significantly lower in the malnourished children than that of their healthy counterparts (p < 0.001). RRV was found to be significantly higher in the malnourished group (6.11 ± 1.96 cm^3 / kg vs 5.40 ± 1.11 cm^3 / kg in control group; p value 0.030) [Table 2].

Table 2. Comparison of right and left kidney parameters between malnourished and control group

Kidney parameters	Right Kidney			Left Kidney		
	Mal-nourished	Control	Significance	Mal-nourished	Control	Significance
Length (cm)	0.80 ± 5.90	0.83 ± 6.40	t = (-) 3.045, p = 0.003, df = 98	0.83 ± 6.04	0.85 ± 6.62	t = (-) 3.471, p = 0.001, df = 98
Width (cm)	0.50 ± 2.58	0.42 ± 2.81	t = (-) 2.52, p = 0.013, df = 98	0.49 ± 2.63	0.43 ± 2.84	t = (-) 2.243, p = 0.027, df = 98
Thickness (cm)	0.50 ± 2.73	0.40 ± 3.06	t = (-) 3.628, p < 0.001, df = 98	0.51 ± 2.79	0.40 ± 3.12	t = (-) 3.593, p = 0.001, df = 98
Volume (cm^3)	10.37 ± 23.27	10.67 ± 30.06	t = (-) 3.230, p = 0.002, df = 98	10.72 ± 24.74	11.31 ± 31.97	t = (-) 3.279, p = 0.001, df = 98
Relative Renal Volume (cm^3 / kg)	Malnourished		Control		Significance	
	1.96 ± 6.11		1.11 ± 5.40		t = 2.198, p = 0.030, df = 98	

The majority of the malnourished children in this study were having grade II malnutrition (34%), followed by grade I (28%), grade III (20%) and grade IV (18%) malnutrition. Both right and left kidney lengths decreased significantly with increase in the severity of malnutrition (p value 0.007). But, the same significance has not been found with kidney width, thickness or volume. The change in RRV was also not significant with increasing severity of malnutrition [Table 3].

Table 3. Differences in various kidney parameters in the malnourished group between different grades of malnutrition

Kidney parameters Grade I		Grade of malnutrition				Significance (ANOVA)
		Grade II	Grade III	Grade IV		
Right Kidney	Length (cm)	0.735 ± 6.40	0.745 ± 5.90	0.719 ± 5.76	0.695 ± 5.28	F = 4.542, p = 0.007
	Width (cm)	0.370 ± 2.79	0.452 ± 2.59	0.640 ± 2.39	0.535 ± 2.43	F = 1.658, p = 0.189
	Thickness (cm)	0.351 ± 2.97	0.519 ± 2.79	0.517 ± 2.46	0.507 ± 2.55	F = 2.774, p = 0.052
	Volume (cm^3)	8.820 ± 28.62	10.425 ± 23.69	10.487 ± 19.41	9.761 ± 18.43	F = 2.601, p = 0.063
Left Kidney	Length (cm)	0.785 ± 6.62	0.674 ± 5.94	0.808 ± 5.91	0.777 ± 5.48	F = 4.624, p = 0.007
	Width (cm)	0.407 ± 2.82	0.476 ± 2.69	0.467 ± 2.46	0.583 ± 2.41	F = 1.943, p = 0.136
	Thickness (cm)	0.360 ± 3.00	0.560 ± 2.84	0.567 ± 2.59	0.469 ± 2.57	F = 2.044, p = 0.121
	Volume (cm^3)	9.182 ± 30.24	10.718 ± 25.17	10.057 ± 21.27	11.003 ± 19.23	F = 2.614, p = 0.062
Relative Renal Volume (cm^3/kg)		1.148 ± 5.49	1.688 ± 6.07	1.778 ± 5.85	3.082 ± 7.42	F = 1.967, p = 0.132

There were no significant differences in the kidney sizes between male and female children in either of the groups [Data not shown]. Significant difference had also not been found between the kidney parameters of right and left side in any of the 2 groups. However, mean values of length, width, thickness and volume were more with the left kidney compared to the right one [Data not shown].

Right and left kidney volumes were best correlated with the height of the child (p value < 0.001), followed by their weight and age (p < 0.001) in both the groups [Data not shown]. In the combined group (N = 100), all the anthropometric parameters (i.e. age, weight, height, MAC and SFT) were found to have significant correlation with all the renal parameters. Strongest positive correlation was between RRV and height, followed by renal volumes and weight and renal volumes and age (p < 0.001). RRV was found to have significant negative correlation with MAC (p value 0.016) and SFT (p value 0.003). Skinfold thickness was least correlated with kidney parameters among all others [Table 4]. But, multiple regression analysis showed that only height and weight significantly affected the kidney lengths and volumes in the combined group (p value < 0.05) [Table 5].

Table 4. Correlation between anthropometric parameters and kidney parameters in the combined group (N = 100)

Kidney parameters	Age		Weight		Height		MAC		SFT	
	r	p	r	p	r	P	r	p	r	P
RK-L (cm)	0.756	0.000	0.806	0.000	0.826	0.000	0.403	0.000	0.314	0.001
RK-W (cm)	0.770	0.000	0.742	0.000	0.811	0.000	0.418	0.000	0.254	0.011
RK-T (cm)	0.753	0.000	0.787	0.000	0.807	0.000	0.426	0.000	0.297	0.003
RK-Vol (cm^3)	0.824	0.000	0.834	0.000	0.866	0.000	0.423	0.000	0.285	0.004
LK-L (cm)	0.747	0.000	0.804	0.000	0.830	0.000	0.414	0.000	0.308	0.002
LK-W (cm)	0.764	0.000	0.744	0.000	0.808	0.000	0.414	0.000	0.245	0.014
LK-T (cm)	0.724	0.000	0.768	0.000	0.783	0.000	0.449	0.000	0.306	0.002
LK-Vol (cm^3)	0.814	0.000	0.836	0.000	0.866	0.000	0.445	0.000	0.291	0.003
RRV (cm^3/kg)	0.306	0.002	0.995	0.000	0.230	0.022	(-) 0.240	0.016	(-) 0.297	0.003

Table 5. Multiple regression analysis for prediction of different kidney dimensions in the combined group (n=100)

Kidney Dimensions	Regression Equation	Significance (ANOVA)
RK-L (cm)	[(Age(m)] + [0.14 × Wt(kg)***] + [0.034 × Ht(cm)**] – [0.096 × MAC(cm)] + [0.003 × SFT (mm × 0.007] – 3.369	F = 49.605 p = 0.000
RK-W (cm)	[*(Age (m)] + [0.019 × Wt (kg)] + [0.017 × Ht (cm)*] + [0.062 × MAC (cm)] - [0.042 × SFT (mm × 0.005] + 0.623	F = 40.028 p = 0.000
RK-T (cm)	[(Age (m)] + [0.066 × Wt (kg)**] + [0.013 × Ht (cm)] + [0.006 × MAC (cm)] - [0.022 × SFT (mm × 0.002] + 1.296	F = 41.067 p = 0.000
RK-Vol (cm^3)	[(Age (m)] + [1.606 × Wt (kg)***] + [0.291 × Ht (cm)*] + [0.027 × MAC (cm)] - [0.575 × SFT (mm × 0.084] + 8.964 (-)	F = 71.241 p = 0.000
LK-L (cm)	[(Age (m)] + [0.136 × Wt (kg)**] + [0.044 × Ht (cm)**] - [0.069 × MAC (cm)] - [0.020 × SFT(mm × 0.012] - 2.884	F = 50.187 p = 0.000
LK-W (cm)	[*(Age (m)] + [0.025 × Wt (kg)] + [0.018 × Ht (cm)*] + [0.061 × MAC (cm)] - [0.047 × SFT (mm × 0.003] + 0.679	F = 39.786 p = 0.000
LK-T (cm)	[(Age (m)] + [0.058 × Wt (kg)*] + [0.013 × Ht (cm)] + [0.036 × MAC(cm)] - [0.032 × SFT (mm × 0.002] + 1.151	F = 34.788 p = 0.000
LK-Vol (cm3)	[*(Age(m)] + [1.601 × Wt (kg)**] + [0.348 × Ht (cm)*] + [0.505 × MAC (cm)] - [0.845 × SFT (mm × 0.053] + 14.334(-)	F = 70.754 p = 0.000
RRV (cm^3/kg)	[(Age (m)] - [0.309 × Wt (kg)**] + [0.081 × Ht (cm)*] - [0.014 × MAC (cm)] - [0.137 × SFT (mm ×0.017] + 3.275	F = 7.513 p = 0.000

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Discussion

In the present study, mean PCI of the control group was significantly greater than the malnourished group, which reinforces the effect of economic deprivation as a strong etiologic factor behind the increased prevalence of malnutrition in the developing countries. The malnourished children had significantly lower weight, MAC, SFT, BMI and BSA. But, children of the two groups did not differ significantly with regard to their height / length, though mean height was more in the control group. Insignificant height difference may be due to the fact that we excluded children with chronic diseases and also those born SGA, factors which could affect height significantly. The length, width, depth and volume of both left and right kidneys in the malnourished children were significantly lower than that of the healthy controls ($p < 0.001$).

The primary cause for the decreased kidney size in malnourished children is the decreased protein intake which hampers the normal growth and development of the renal tubular cells, particularly of the proximal tubules. Malnutrition produces certain changes such as decreased multiplication of cells and decreased cell size (Mostly due to the depletion in the enzyme granules and cellular organelles).[13] It has been established that though the nephron formation is complete by birth, the glomeruli and renal tubular cells continue to grow in the post natal period and if there is inadequate dietary intake, and particularly protein, it decreases the cell size and contributes to the overall decrease in size of the kidneys.

In contrast to all other measurements, the malnourished children had significantly higher RRV than healthy controls. This may be explained partially by increased solute load due to the catabolic state in malnourished children and their relatively high lean body mass as a percentage of total body weight.[7] Body composition in the form of lean body mass has a significant impact on kidney size with leaner child has greater kidney volume.[7] In support with this suggestion, a comparison between kidney weight in lean and obese adults showed decreased relative kidney weight in the obese individuals.[14]

The more the degree of malnutrition, the effect on kidney is more pronounced. This statement is well supported in this study, where both right and left kidney lengths have been shown to decrease significantly with increase in the severity of malnutrition. But, the same significance has not been found with kidney width, thickness or volume. In some instances, there was even an increase in the mean value of kidney parameters with increasing grade of malnutrition, probably because of the differences in age distribution among the children with different grades of malnutrition. In the present study, no significant difference was found in the kidney sizes of male and female children in either of the groups. There are differences in opinion regarding the effect of gender on kidney size. Some reports showed larger kidneys in boys than girls,[15,16] while others found no gender differences.[17-20]

Mean values of left kidney parameters were found to be higher than that of the right one in both the groups, but the difference was not statistically significant. Previously published data show controversies concerning differences between left and right kidneys.[7,17,18,21] However, there has been no disagreement about the left kidney being the longest.[11,17,19,22,23]

Correlation between different anthropometric and kidney parameters were found to be highly significant in the present study. It is utterly important to know whether the kidney size of a child is appropriate for his age or anthropometric measurements. Kidneys which are reported as "small" in USG usually undergo additional invasive imaging procedures, including renal scan and voiding cysto-urethrography, in order to exclude hypoplastic–dysplastic kidney or atrophic kidney secondary to reflux nephropathy. If prior knowledge about relationship of small kidneys with malnutrition exists, unnecessary imaging procedures can be avoided. Moreover, by regression analysis, we have tried to formulate equations for various renal parameters, which can help us to predict the expected value for a given child, if we can just perform a thorough anthropometric survey of that child.

There is increasing understanding of the importance of organ growth and differentiation early in life as possible predictors of disease in adulthood.[7] Poor renal growth is thought to have some long-term consequences in the form of increased risk of developing hypertension, or tendency to develop chronic kidney disease in the future.[24,25] But, whether the risk of hypertension or kidney disease in later life will be greater in case of malnourished children than for healthy subjects, could not be predicted from this study. This point can be clarified with further longitudinal studies.

Conclusions

Malnourished children had smaller kidneys than the normally nourished children, signifying a mention-worthy role of nutrition in kidney growth. However, RRV of children with malnutrition was higher than the controls. These differences in the kidney size of malnourished children should be kept in mind while assessing their renal ultrasound.

References

1. Aydin E, Ayfer G, Yaser B, Munat T, Halil K. The effect of malnutrition on kidney size in children. Pediatr Nephrol. 2007; 22: 857-63.
DOI: 10.1007/s00467-006-0338-5
2. Sawaya AL, Martins PA, Grillo LP, Florencio TT. Long-term effects of early malnutrition on body weight regulation. Nutr Rev. 2004; 62: S127–S133.
DOI: 10.1111/j.1753-4887.2004.tb00082.x
3. Effmann EL, Ablow RC, Siegel NJ. Renal Growth. Radiol Clin North Am. 1977; 15: 3-17.
PMID: 847111
4. Schmidt I, Chellakooty M, Boisen KA, Damgaard IN, Kai CM, Olgaard K, et al. Impaired kidney growth in low birth weight children: Distinct effects of maturity and weight for gestational age. Kidney Int. 2005; 68: 731–40.
DOI: 10.1111/j.1523-1755.2005.00451.x
5. Gado RD, Perrone L, Del Gaizo D, Sommantico M, Polidori G, Cioce F, et al. Renal size and function in patients with neuropathic bladder due to myelomeningocele: the role of growth hormone. J Urol. 2003; 170: 1960–1.
DOI: 10.1097/01.ju.0000091874.91613.af
6. Schmidt IM, Damgaard IN, Boisen KA, Mau C, Chellakooty M, Olgaard K, et al. Increased kidney growth in formula fed versus breast-fed healthy infants. Pediatr Nephrol. 2004; 19: 1137–44.
DOI: 10.1007/s00467-004-1567-0

7. Schmidt IM, Molgaard C, Main KM, Michaelsen KF. Effect of gender and lean body mass on kidney size in healthy 10-year-old children. Pediatr Nephrol. 2001; 16: 366–70. DOI: 10.1007/s004670100568

8. Gupta P, Shah D. Protein Energy Malnutrition. In: Ghai OP, Gupta P, Paul VK, editors. Ghai Essential Pediatrics. 6th ed. New Delhi: CBS Publishers & Distributors; 2004. p. 101-18.

9. Du Bois D, Du Bois EF. A formula to estimate the approximate surface area if height and weight be known. Arch Intern Med. 1916; 17: 863–71.
PMID: 2520314

10. Ruiz L, Colley JRT, Hamilton PJS. Measurement of Triceps skinfold thickness an investigation of sources of variation. Brit J Prev Soc Med. 1971; 25: 165-7.
DOI: 10.1136/jech.25.3.165

11. Emamian SA, Nielsen MB, Pedersen JF, Ytte L. Kidney Dimensions at Sonography: Correlation with Age, Sex and Habitus in 665 adult volunteers. Am J Roentgenol. 1993; 160: 83-6.
DOI: 10.2214/ajr.160.1.8416654

12. Zenkl M, Egghart G, Muller M. The normal kidney size in children. An ultrasound study. Urologe A. 1990; 29: 32–8.
PMID: 2180169

13. Hay RW, Stanfield JP. The pathology of protein-energy malnutrition. Chapter 3 in : Alleyne GAO, Hay RW, Picous DI, Stanfield JP, Whitehead RG. Protein-energy Malnutrition. 1st edition. New-Delhi: Jaypee Brothers Medical Publishers; 1989, pp 26-37.

14. Kasiske BL, Umen AJ. The influence of age, sex, race, and body habitus on kidney weight in humans. Arch Pathol Lab Med. 1986; 110: 55–60.
PMID: 3753571

15. Scott JE, Hunter EW, Lee RE, Matthews JN. Ultrasound measurement of renal size in newborn infants. Arch Dis Child. 1990; 65: 361-4.
DOI: 10.1136/adc.65.4_spec_no.361

16. Miletic D, Fuckar Z, Sustic A, Mozetic V, Stimac D, Zauhar G. Sonographic measurement of absolute and relative renal length in adults. J Clin Ultrasound. 1998; 26: 185–9. DOI:10.1002/(sici)1097-0096(199805)26:4<185::aid-jcu1>3.0.co;2-9

17. Dinkel E, Ertel M, Dittrich M, Peters H, Berres M, Wissermann-Schulte H. Kidney Size in childhood. Sonographical growth charts for kidney length and volume. Pediatr Radiol. 1985; 15: 38-43.
DOI: 10.1007/BF02387851

18. Jelen Z. The value of ultrasonography as a screening procedure of the neonatal urinary tract: a survey of 1021 infants. Int Urol Nephrol. 1993; 25: 3–10.
DOI: 10.1007/BF02552248

19. Dremsek PA, Kritscher H, Böhm G, Hochberger O. Kidney dimensions in ultrasound compared to somatometric parameters in normal children. Pediatr Radiol. 1987; 17: 285–90.
DOI: 10.1007/BF02388240

20. Schmidt IM, Main KM, Damgaard IN, Mau C, Haavisto AM, Chellakooty M, et al. Kidney growth in 717 healthy children aged 0–18 months: a longitudinal cohort study. Pediatr Nephrol. 2004; 19: 992–1003.
DOI: 10.1007/s00467-004-1479-z

21. Han BK, Babcock DS. Sonographic Measurements and Appearance of Normal Kidneys in children. Am J Roentgenol 1985; 145: 611-6.
DOI: 10.2214/ajr.145.3.611

22. Haugstvedt S, Lundberg J. Kidney size in normal children measured by sonography. Scandinavian J Urol and Nephrol. 1980; 14(3): 251-5.
DOI: 10.3109/00365598009179571

23. Konus OL, Ozdemir A, Akkaya A, Erbas G, Celik H, Isik S. Normal liver, spleen and kidney dimensions in neonates, infants and children: evaluation with sonography. Am J Roentgenol. 1998; 171: 1693-8.
DOI: 10.2214/ajr.171.6.9843315

24. Hoy WE, Douglas-Denton RN, Hughson MD, Cass A, Johnson K, Bertram JF. A stereological study of glomerular number and volume: Preliminary findings in a multiracial study of kidneys at autopsy. Kidney Int Suppl. 2003; 83: S31–S37.
DOI: 10.1046/j.1523-1755.63.s83.8.x

25. Singh GR, Hoy WE. Kidney volume, blood pressure, and albuminuria: findings in an Australian Aboriginal community. Am J Kidney Dis. 2004; 43: 254–9.
DOI: 10.1053/j.ajkd.2003.10.015