ORIGINAL ARTICLE

Sonographic nomogram of paediatric renal size in Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM)

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ABSTRACT

Introduction: A person's childhood is an important period of growth, and also one's most vulnerable, as one can be exposed to various pathologies, for example those that could affect the growth of one's kidney. Asians are physiologically different from Caucasians, and the nomogram renal size obtained from a Western population (mostly of Caucasians) is not be suitable for representing Asian children. As such a nomogram on paediatric renal size derived from Malaysia is needed.

Methods: A total of 109 (64 males and 45 females) aged 0-12 in Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM) took part in this study. They underwent ultrasonography of both kidneys, and their demographic and anthropometric data were collected. The mean and standard deviations of the renal length and renal volume according to their age groups was calculated, and the final data was compared to the ones reported by Rosenbaum et al. (1984).

Result: Body weight and Body Surface Area (BSA) of the children reported the strongest correlation with renal size. Significant differences were found between local and the data from Rosenbaum et al (1984). A nomogram on paediatric renal size based on children in PPUKM was then created.

Discussion: Ultrasonography is regarded as the standard method for determining renal size. Body weight and BSA were both strongly correlated with renal size. It was shown that the widely used nomograms derived from data obtained from Caucasian was not suitable to represent the population of Malaysian children.

KEY WORDS:
paediatric, renal size, ultrasound, nomogram, demographic data

INTRODUCTION

Childhood represents an important growth period. Kidneys, which is an important organ, are commonly afflicted by many diseases during this period, such as urinary tract infection, vesicoureteric reflux, congenital anomalies of the kidneys, or renal parenchymal disease.[1,2] Kidneys afflicted by diseases show signs such as changes to its serum biochemical markers (creatinine, urea and electrolytes). Chronic derangement of renal function could also affect kidney growth.[1,3] Kidney dimensional parameters, such as renal bipolar length, parenchymal thickness, and renal volume are all used to assess kidney sizes.[1,2,4] In a growing child, the intra-abdominal organs grow, and their sizes change accordingly. Thus any measurement of the intra-abdominal organ dimensional parameter needs to be correlated with the age of the child, and other anthropometric data.[4,5] An abnormal kidney in the paediatric population has not been properly defined in the Malaysian setting. Instead, nomogram from the West is used as a reference in clinical practice. As one of the earliest paper published pertaining to the sonographic measurement of normal paediatric kidney size, Rosenbaum et al., is widely used in many centres in Malaysia and around the world.[6] This, however, may not be suitable due to the differences between the anthropometric measurement of Western (Caucasian) and Malaysian children, which directly influence kidney sizes.[7,8] Malaysian children are generally smaller in size, which would imply a smaller kidney.[8] Therefore, there is a need to produce a separate nomogram of paediatric kidney size. Many countries, such as China, Japan, Korea, India, Nigeria, Turkey and Hong Kong have begun developing their own respective nomograms.[5-10] It should also be pointed out that ethnicity could well play a role towards the determination of normal kidney sizes in children.[11]

Traditionally, excretory urography was used to determine kidney sizes. This procedure has now been replaced with ultrasonography.[1,4,12] Computed tomography (CT) scan, magnetic resonance imaging (MRI) and nuclear studies can also be used to determine kidney size, but the former two involve the usage of radiation, while MRI scans take too long, which makes it unsuitable for use in children.[13-16] Ultrasonography is regarded as a safe and non-invasive examination. It does not involve radiation and can be used for pre-natal and post-natal foetal assessments. Due to its safety, flexibility, and cost effectiveness, ultrasonography is seen as an ideal tool for determining kidney sizes of children.[1]

The objectives of this study include describing the normative values of renal dimension parameters, which is made up of the mean kidney bipolar length and mean kidney volume using ultrasonography. We also intend to elucidate the correlation(s) between kidney dimensional parameters to that of age, height, weight, body surface area (BSA), gender,

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and ethnicity, and finally, compare local data to internationally published reference data used in the radiology department of the Pusat Perubatan Universiti Kebangsaan Malaysia (PPUKM). To the best of our knowledge, comparing Malaysian data to internationally used reference data has yet to be elucidated in Malaysia.

MATERIALS AND METHODS

This is a cross-sectional study conducted between June and December 2017 in PPUKM. Participant were selected using convenience sampling. The inclusion criteria were: term child age 0-12 years old; and has no previous/current history of renal or any other form of chronic diseases that could affect their kidney's growth and is a non-syndromic child. A total of 112 children, who were apparently healthy, took part in this study. Informed consents were obtained from the guardians. The participants consisted of children who were admitted to the paediatric ward, attending the clinic, or the healthy siblings of the patients.

Data Collection

The gender, age (calculated to the nearest month based on date of birth to date of examination), ethnicity, weight (in kilograms), and height (in centimetres) of each participant was recorded during the examination.

Equipment

Ultrasonography was performed on all children using Mindray Diagnostic Ultrasound System Model DP – 50, with a convex probe 3.5Mhz or a microconvex probe of 6.5Mhz.

Ultrasound Examination

The participants were scanned in a supine position, and if the sonographic window was inadequate, scanning was conducted in the left or right lateral decubitus position. A minimum of three images were taken for both longitudinal and transverse sections of each kidney. Three of the best images for each longitudinal section for each kidney were measured to determine its maximum bipolar length and parenchymal thickness, while three of the best images for each transverse section for each kidney were measured for its anteroposterior (AP) diameter and width at the hilum level. The three readings were then averaged.

Statistical analysis

SPSS version 22.0 was used for statistical analysis. The participants were divided into 15 groups based on their age. Those under one-year-old were grouped into four, with a shorter 3-month interval, and categorized as 0.25, 0.50, 0.75, and 1.0 year olds.[6] Those more than a year old was grouped as an average between two immediate age groups, i.e., those aged 1-2 were grouped as 1.5 year old, age from 2-3 were grouped as 2.5 year old, and so forth. The mean kidney length, mean kidney volume, and mean parenchymal thickness were calculated for each age group. The renal volume was calculated using the ellipsoid formula (bipolar length x AP diameter x Width x 0.52),[5] while the body surface area was calculated using the formula $[(\text{body height (cm)} \times \text{body weight (kg)}/3600]^{1/2}$. Correlations were made between the age, ethnicity, gender, body height, body weight, and BSA with the mean kidney length, mean kidney volume, and mean parenchymal thickness. A P value of <0.05 was taken as a significant value. Though the distribution is not strictly in Gaussian's, but as the sample size is more than 30, parametric test is applied. The mean kidney length for each age group was compared with the means of the corresponding age group, as per Rosenbaum et al.[6] Even though the sample size for subgroup analysis was less than 30, the mean was used for comparison as Rosenbaum et al., also used mean in his article.[6]

RESULTS

Out of the 112 participants, three children were excluded after the ultrasonography due to incidental findings of hydronephrosis and renal cysts. The demographic data of the remaining 109 children were as shown in Table I. The mean kidney length and mean kidney volume increased progressively with age (Table II).

There was no significant difference in the mean kidney length (p=0.52) and mean kidney volume (p=0.76) between genders. There was also no significant difference noted on the mean kidney length between ethnicities (p=0.086), but there was a significant difference in the mean kidney volume (p=0.033).

There was strong and positive correlation between age and mean kidney length, mean kidney volume, and mean parenchymal thickness (r=0.83, 0.79, 0.63), between height and mean kidney length, mean kidney volume, and mean parenchymal thickness (r=0.91, 0.85, 0.70), between weight and mean kidney length, mean kidney volume, and mean parenchymal thickness (r=0.88, 0.91, 0.70), and between BSA and mean kidney length, mean kidney volume, and mean parenchymal thickness (r=0.92, 0.91, 0.72). The best-reported correlations with mean kidney length was BSA (r=0.92, p<0.001), while the best-reported correlation for mean kidney volume were BSA (r=0.91, p<0.001) and weight (r=0.91, p<0.001).

Comparison with Rosenbaum et al. study (1984)

The subjects in this study were divided as per the groupings in Rosenbaum et al., for ease of comparison.6 (Table III) Of the 15 groups, four had more than 10 children in each group, with a range of 12-17 children per group, while the counterparts in Rosenbaum et al ., comprised of 12-30 children per group. The mean kidney length in these four groups were compared with the corresponding age group outlined in Rosenbaum et al.[6] The groups with a mean age of 1.5, 2.5, and 4.5 years old showed a significant difference in its mean kidney length. As for the group with a mean age of 3.5 years old, there was no significant difference in their mean kidney length (p = 0.3380) (Table IV). A nomogram was created from the data and shown in Figure 1.

DISCUSSION

Ultrasonography is the most widely used modality for kidney size assessment, due to its safety, availability, and cost effectiveness. A growing child will report different kidney sizes throughout the multiple stages of development. A Malaysian nomogram is thus needed as a reference. Children from

Table I: Demographic data

Parameter	Group	Number	Mean Kidney Length	Mean Kidney Volume
Gender (number)	Male	64	P=0.52	P=0.76
	Female	45	P=0.52	P=0.76
Ethnicity (number)	Malay	91	P=0.086	P=0.0033
	Chinese	14		
	Indian	3		
	Orang Asli	1		
Age	Range	1 month – 11.9 years	NA	NA
	Mean	4.3 years	NA	NA

p<0.05 as statistically significant, NA= not available.

Table II: Summary of number of patients in age group, mean kidney length and mean kidney volume

Age in Subgroups [year]	Number of Patients	Age Interval [M=month, Y=year]	Mean Kidney Length, [cm](SD)	Mean Kidney Volume, cm^3 (SD)
0.25	3	0-3M	4.56 (0.31)	15.79(1.77)
0.50	4	4-6M	5.39(0.17)	22.34(4.05)
0.75	3	7-9M	5.74(0.82)	27.28(9.31)
1.00	4	10-12M	5.76(0.46)	26.25(6.04)
1.50	12	1-2Y	6.21(0.44)	33.29(5.35)
2.50	17	2-3Y	6.43(0.38)	34.43(5.06)
3.50	15	3-4Y	7.18(0.46)	45.30(7.26)
4.50	15	4-5Y	7.05(0.42)	43.73(11.16)
5.50	6	5-6Y	7.27(0.66)	48.30(16.77)
6.50	6	6-7Y	7.45(0.63)	58.60(14.57)
7.50	7	7-8Y	8.10(0.36)	58.66(6.90)
8.50	7	8-9Y	7.99(0.76)	57.03(11.61)
9.50	5	9-10Y	7.67(0.40)	60.29(11.11)
10.50	3	10-11Y	8.16(0.32)	68.02(4.74)
11.50	2	11-12Y	10.02(0.92)	128.23(27)

Table III: Summary of group observation - mean renal length

Average age*	Interval*	Mean Renal Length (cm)	SD	n
0 month	0–1week	4.48	0.31	10
2 month	1week–4month	5.28	0.66	54
6 month	4–8month	6.15	0.67	20
10 month	8month–1year	6.23	0.63	8
1½	1-2	6.65	0.54	28
2½	2-3	7.36	0.54	12
3½	3-4	7.36	0.64	30
4½	4-5	7.87	0.50	26
5½	5-6	8.09	0.54	30
6½	6-7	7.83	0.72	14
7½	7-8	8.33	0.51	18
8½	8-9	8.90	0.88	18
9½	9-10	9.20	0.90	14
10½	10 - 11	9.17	0.82	28
11½	11-12	9.60	0.64	22
12½	12-13	10.42	0.87	18
13½	13-14	9.79	0.75	14
14½	14-15	10.05	0.62	14
15½	15-16	10.93	0.76	6
16½	16-17	10.04	0.86	10
17½	17-18	10.53	0.29	4
18½	18-19	10.81	1.13	8

*Years unless specified otherwise; SD-Standard Deviation, n= number of children
Sourced from Rosenbaum et al (6).

Table IV: Comparison of mean kidney length between data from PPUKM and Rosenbaum et al.

Age in Subgroups	PPUKM	Rosenbaum	Significant Difference
	Mean Kidney Length (N) (SD)		
1.5 (1-2 year)	6.21 (12)(0.44)	6.65(28)(0.54)	Yes (p=0.0175)
2.5 (2-3 year)	6.43 (17(0.38)	7.36(12) (0.54)	Yes(p<0.0001)
3.5 (3-4 year)	7.18 (15)(0.46)	7.36(30)(0.64)	No (p=0.3380)
4.5 (4-5 year)	7.05 (15)(0.42)	7.87(26)(0.50)	Yes (p<0.0001)

p<0.05 as statistically significant; SD-Standard Deviation, N= number of children

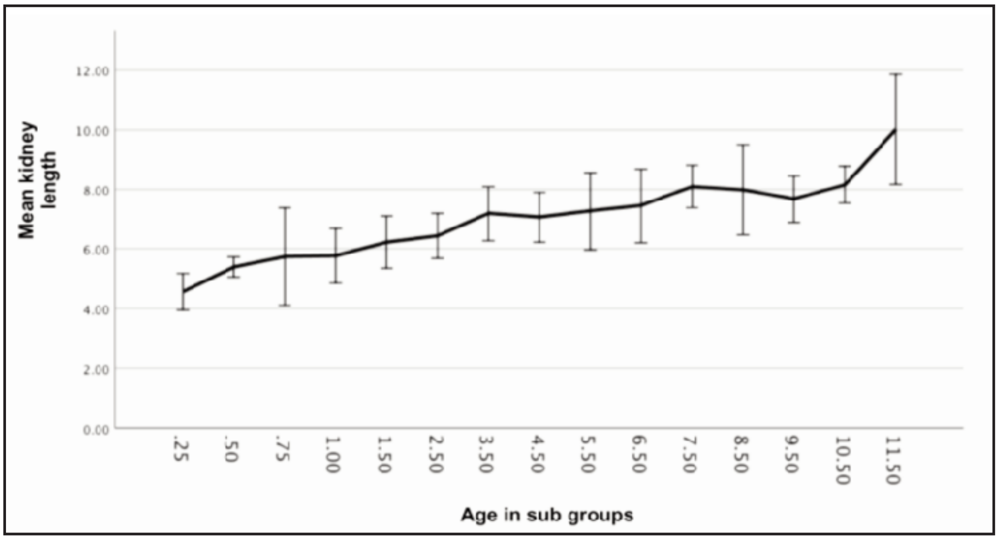

Fig. 1: Mean kidney length ±2 Standard Deviation against age in sub groups

different demographic backgrounds will have different body growth rates. Generally, Caucasian children have larger body habitus relative to their Asian counterparts, and as a result of this, there would also be difference in their respective kidney sizes.[8] This is why many countries developed their own nomograms to better represent their respective populations.[5-10] As one of the earliest publications on normal kidney size for children was acquired via sonography, the nomogram reported by Rosenbaum et al., was used as a reference by many in world, including Malaysia.[6]

There is a wide range of subjects included in each age group in previous studies. The first ever study on paediatric kidney size was performed in 1980 examining 46 children.[17] The number of subjects in each of the age group was as low as four subjects per group, as per Rosenbaum et al., and as high as 379 per group, as per study conducted in Hong Kong.[6,8] There were studies with very strong data, such as from China, which had at least a minimum of 100 subjects per age group, and Hong Kong, which had on average 200–300 subjects per age group.[7,8]

To the best of our knowledge, none of the above studies suggested a minimum number of subjects required for each age group. However, in an unrelated study on paediatric neuropsychology, Bridges et al., suggested that 50-75 subjects are needed in a group for a normative study to obtain a confidence level of 95%.[18] Lesser subjects (<50) might result in over-pathologising, while more subjects (>75) would not be cost effective. Other than the studies in China and India, most studies had less than 50 subjects per age group, with an average of 10–20 subjects in each age group. Therefore, our study only utilised four groups with more than 10 subjects per group for comparison, as per Rosenbaum et al.[6]

The mean kidney length of all of the age groups obtained in this study was generally smaller than those reported in Rosenbaum et al.[6] Of the four groups, three showed significant statistical difference in its mean kidney length when compared to the corresponding group on Rosenbaum et al.[6] This suggests that the data from Rosenbaum et al., might not be optimal for Malaysia's clinical practice as a reference, as we would overestimate the size of the kidneys of Malaysian children. To explain such a significant difference, YB Bong et al., showed that for the median centile growth, children from the United States of America were taller and heavier than their counterparts in Malaysia, which are most likely due to genetic and environmental factors.[19] In this study, the mean kidney length is strongly and positively correlated with body weight and BSA, which goes to explain why Western children have relatively larger kidney sizes. Meanwhile, the group with a mean age of 3.5 years reported no significant difference with those reported in Rosenbaum et al.[6] One possible explanation is the fact that from the mean age of 2.5-3.5 years, there was a steady increase in the mean kidney length in our study, but the mean kidney length remained static at 7.36 cm for both mean ages of 2.5 and 3.5 years in Rosenbaum et al. [6] This led to a smaller difference in the kidney size for this age group between the ones reported in this study and the ones reported in Rosenbaum et al.[6] As the subgroup sample is less than 30, one might have to consider repeating the trend description with larger cohorts, so that parametric test with reliable standard deviation or 95% confidential interval could be ascertained in the general paediatric population of Malaysia.

No significant difference(s) in kidney size were evident in the context of gender, which is also supported by previous studies.[9,20,21] There was no significant difference between the mean kidney length, but there was a significance difference between the mean kidney volume between the different ethnicities taking part in this study. The mean renal volume was an estimation calculated using the ellipsoid formula, which means that it could be over or under estimated (due to calculation errors). As the mean renal volume is prone to calculation error and is impractical in daily clinical practice, the mean kidney length was used instead to represent renal size(s). Adeela et al., showed that there is a significance difference in renal size between ethnicities.[11] This contradictory finding was likely because in this study, we compared children of different ethnicities who were born and raised in the same country with similar demographics, while in Adeela et al., the studied population comprised of international students from multiple ethnicities from countries.[11]

In this study, the renal size is significantly correlated with age, body height, body weight, and BSA, as reported previously.[9] Body weight and BSA were shown to be best correlated with mean kidney length and mean kidney volume. Body weight is one of the parameters used to calculate the BSA, and it is not surprising that BSA has the same degree of correlation with body weight. BSA was previously shown to correlate well with kidney length, while body weight was shown in several studies to have a strong correlation with mean kidney length and mean kidney volume, though not to the extent of the strength of the relationship between body weight and BSA.[9,22-24] Age and body height are strongly and positively correlated with mean kidney length. This was also reported in several other studies, where kidney length is best correlated with body height.[17,23] In many studies body height was also suggested as the primary factor in deciding the normality of kidney size, relative to age or body weight.[9,25] Other than kidneys, body weight was also reported to correlate well with other intra-abdominal organs, such as the liver and spleen.[4] Although renal volume is better in representing the overall size, measuring the renal volume in clinical practice is impractical, as it requires more measurements, is prone to error, and is inaccurate.[8,26] 3D ultrasonography is able to provide a faster and more accurate assessment of renal volume, however, it is not readily available everywhere. In most centres, measuring only the mean kidney length instead of the kidney volume is an acceptable approach for monitoring kidney growth.[8] The calculation of body surface area is seen as time consuming, and might not be adaptable in a busy clinical setting. However, as most studies conducted in other countries showed that either body weight or body height is best correlated with kidney length, then probably body surface area, which is a product of both body height and body weight, should be used instead.[8,9]

CONCLUSION

Sonographic assessment of kidney is a daily routine in radiology practice. Any deviation of kidney size from the reference could be due to an underlying illness, and remedial action needs to be taken early to prevent irreversible damage to the kidneys. An accurate reference, which is created based on the local normal population, is required, as data from other countries may not be representative of the local population. This study reported the first sonographic nomogram of paediatric kidney size based on healthy children presented to PPUKM, Malaysia. It also highlighted the difference between local and western data, and elucidated the importance of having a locally developed nomogram. However, we cannot extrapolate the results since convenience-sampling approach was used and our sample size was relatively small. We recommend that future studies should include an appropriate sample size with appropriate sampling method from more centres in all age groups, to better represent the local population.

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