Comparison of Renal Size among Different Ethnicities

Adeela Arooj, Jostinah Lam, Yeoh J.Wui, Eko Supriyanto

Abstract— Renal ultrasonography is a relatively inexpensive, quick, non-invasive and radiation-free imaging modality to diagnose a range of kidney (renal) diseases. There is a close relationship between renal size and its function. Variation in kidney sizes and shape can be associated with different kidney diseases. Studies show that renal size and measurements are influenced by some factors such as age, ethnicity, gender, weight and height. Commonly, measurements of renal size of any age are compared with the measurements that are predicted by standard nomograms. However, the current nomograms which are widely used locally are derived from studies based on western population of relatively small sample sizes. This paper discussed the influence of weight, height and ethnicity to the size of kidney. This study analysed 200 kidney samples after taking ultrasonic images from normal adult Malaysian population. The renal parameters analysed were length, width, thickness and volume which were plotted against height, weight and gender of the respondent. Results show there is a significant direct positive correlation between renal size and body weight & height. The relationship between body weight and height to kidney size also corresponds to other studies that the higher the body weight, the bigger the kidney is. The results show that the kidney size for similar weight and height is different among different ethnicities. This result is very important in the foundation of a nomogram and kidney diagnosis.

Keywords—renal size, ethnicity, weight, height, Malaysian population, kidney nomogram

I. Introduction

MEDICAL imaging has played an important role in helping physicians to make a medical diagnosis. One such safe and easily available technique worldwide is ultrasound imaging. Ultrasound imaging or also known as ultrasound scanning or sonography is a relatively inexpensive, fast, non-invasive and radiation-free imaging modality. Its portability and simplicity are the characteristics that made it become indispensable modalities over other modalities [16-19]. Ultrasound is excellent in making diagnosis of various diseases or conditions including renal diseases.

A normal human being has 2 bean shaped and red colored kidneys. Kidneys filter the waste products from the blood and excrete them out in the form of urine. A normal functioning kidney should have normal renal volume specific for that particular gender and ethnicity. Evaluation of renal measurements using ultrasound imaging such as length, width and thickness is an important parameter in the diagnosis and also management in many renal disorders as it is known that there is a close relationship between renal size and its function [1]. The evaluation of renal measurements is very important to the clinician as the results can be used to determine the health of the individuals and it can also visualise any abnormalities present in the kidneys [15]. Many studies have shown that the renal size and measurements is influenced by many factors such as age, ethnicity, gender, weight and height [2-4]. It is also known that the left kidney is larger than the right kidney, independent of gender [6-8]. Many studies also concluded that renal measurements variation occurs in nephropathies due to hypertrophic process and/or atrophy [6, 9]. Study done by Mazzotta et al. (2002) found that the most important measurement of renal size is longitudinal length in subjects with normal renal function whereas renal parenchymal volume is, the more exact sonographic parameter in end stage renal disease with failure [1]. Thus, it is imperative to establish the pattern of renal measurements for a more accurate diagnosis.

In Malaysia, every year about 2500 people are diagnosed with kidney failure. Diabetes mellitus and hypertension are the common causes for chronic kidney failure [14]. Worldwide research indicates that one out of 10 adults had kidney problems and by 2015 it is estimated that about 36 premature deaths due to kidney disease will happen [14]. In common practice, measurements of renal size of any age are compared with the measurements that are predicted by standard nomograms. However, to our best knowledge, the current nomograms which are widely used locally were derived from studies based on western population of relatively small sample sizes [5]. Since our currently used renal nomogram in Malaysia is based on the western database, it might lead to the false positive and false negative diagnosis of kidney condition. A wrong diagnosis on a normal kidney will end up with repeated unnecessary scans and patient's anxiety.

Therefore, there is an urge to develop specific ethnic (for instance: Malay ethnic) population nomogram to provide a better accuracy of renal measurements in terms of making a proper medical diagnosis and also during monitoring the

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disease progress. Thus, this research is conducted as a first step in order to formulate a nomogram of renal measurements for Malaysian adult population.

II. Materials and Methods

We analyzed 200 ultrasound images of both left and right kidneys from 100 students who took part in this research. There were 50 female students and 50 male students. The data was then analyzed using Microsoft Excel software.

Before performing kidney ultrasound scanning, several steps were taken in order to make sure the validity of the study. Firstly, operator had to explain the procedure to the respondents and allowed them to ask any questions about the procedure. Then, consent was taken from all the respondents before including them in the study. Only those subjects were included who did not have any prior history of kidney disease and who gave a valid consent.

Before proceeding to ultrasound, height and weight of the respondent was taken. Respondents were reminded to drink 2-3 glasses of fluid and provided a gown. Any type of jewellery or other objects that might interfere with the scan were removed so do the clothing by providing a gown. Clear gel was applied on the patient's skin over the area to be examined before transducer is pressed against the skin and moved around over the area being studied.

Initially the image was taken in supine and later they were asked to turn on the respective side and also to hold their breath for a while. The image was best in this posture. In order to avoid the inter and intra observer variability, only one well trained operator performed the ultrasound on all the respondents using the same ultrasound machine. Ultrasound operator should use all possible comfort measures and complete the procedure as quickly as possible to minimize any discomfort. Once the procedure was completed, the gel was be wiped off. The respondents were informed of the findings.

A. Parameters of Measurement

Longitudinal length: The maximal longitudinal axes should be evaluated from the ventral side (normal value in an adult, 9-12cm). The calipers were placed on the outer edges of the caudal and cranial side in a sagital plane to obtain the maximum longitudinal renal length [20].

Width: From the ventral ultrasonographic section of the kidney, we can also obtain the width that is almost perpendicular to the longitudinal length. (normal range in an adult, 4-7cm).

Thickness: The thickness is measured from the cross section. (normal value in an adult, 3-5mm).

From these 3 parameters that can be obtained from the ultrasound images, we can formulate the volume of the kidney by using the following formula:

$$Volumes = \frac{Thick \times Width \times Length}{2} \quad (1)$$

Fig 1: normal ultrasonic (longitudinal) view Kidney

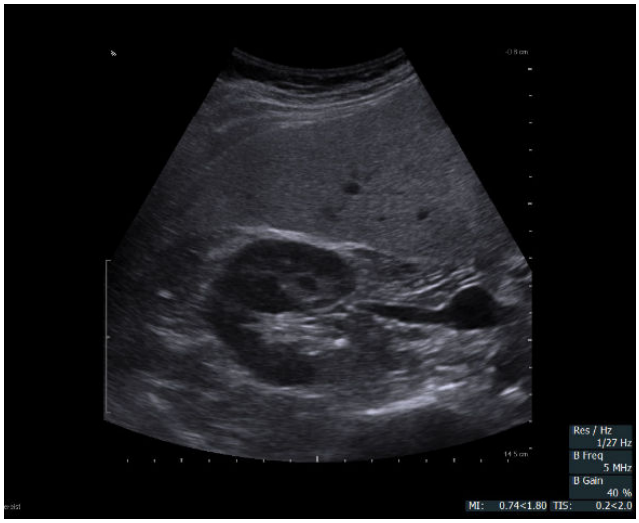

Fig 2: normal ultrasonic (cross-section) view kidney

This formula is the approximation of the ellipsoid formula. However, the value will be a bit smaller as the normal kidney is bean-shaped and not in real ellipsoid shape. The volume can also be more accurately calculated if we use the average of depth in longitudinal and transverse section as follow:

$$\text{Kidney volume} = L \times W \times \{(D1 + D2)/2\} \times 0.523 \quad (2)$$

III. Results and Analysis

Data that were collected were analyzed and the results are as follow:

Table 1: Ultrasound kidney Measurement

Parameters	All		Male		Female	
	Right	Left	Right	Left	Right	Left
Length (cm)	9.7±0.79	9.9±0.96	9.67±0.77	10.04±0.88	9.7±0.84	9.8±1.03
Width (cm)	3.8±0.52	4.4±0.59	3.65±0.45	4.41±0.59	3.9±0.57	4.3±0.58
Thickness (cm)	3.8±0.57	4.3±0.79	3.89±0.58	4.32±0.56	3.7±0.55	4.2±0.98
Volume (cm^3)	71.5±18.84	93.6±27.76	70.74±19.24	97.06±25.07	72.2±18.58	90.15±30.07

Table 2: Weight (kg) vs. Kidney Measurements

Weight (kg)	Right				Left			
	Length (cm)	Width (cm)	Thickness (cm)	Volume (cm^3)	Length (cm)	Width (cm)	Thickness (cm)	Volume (cm^3)
40-50	9.6	3.6	3.6	63.7	9.6	4.1	4.1	77.1
51-60	9.6	3.8	3.8	68.6	10	4.4	4.3	96
61-70	9.7	4	4.1	82	10.2	4.5	4.3	101.7
71-80	10.1	4.1	4.1	85.9	9.7	4.6	4.7	106.8
81-90	10	4.2	4.2	88.2	10.3	4.5	4.4	107.9
91-100	10.3	4.3	4.4	97.4	11	5	5.2	143

Table 3: Height (cm) vs. Kidney Measurements

Height (cm)	Right				Left			
	Length (cm)	Width (cm)	Thickness (cm)	Volume (cm^3)	Length (cm)	Width (cm)	Thickness (cm)	Volume (cm^3)
140-150	9.1	3.7	3.9	73.3	9.6	4.1	3.8	82.1
151-160	9.6	3.9	4.1	77.8	9.9	4.0	4.0	89.6
161-170	9.7	4.1	3.8	87.8	9.8	4.3	4.2	92.5
171-180	9.9	4.3	4.0	90.6	10.2	4.5	4.3	103.16

A total of 100 volunteers were included in this study. Out of the 100 individuals assessed, 51 of them were female and 49 male. The body weight ranged from 40kg to 110kg where the mean was 57.42±10.94kg. The body height ranged from 140cm to 180cm with mean equals to 163.34 ±9.13cm.

Based on Table 1, the mean ranges of normal kidney length were 8.91- 10.49cm and 8.94 – 10.86cm for the right and left kidney of all subjects respectively. The mean length of the left kidney was 10.04±0.88cm for male and 9.8±1.03cm for female. Meanwhile, the average readings for the right kidney were 9.67±0.77cm and 9.7±0.84cm for male and female respectively.

As we can see from Table 1, there is not much difference in the all the parameters i.e., length, weight and thickness of both genders. Same was true for the renal size measurements. Even though we can say that renal size in male population is relatively bigger than female population in this study. However, we can conclude that the left kidney is larger than the right kidney independent of gender. The results that we obtained were comparable with the results from the study done by Mario et al. in 2002.

Based on Table 2, we can see that, there is a significant direct positive correlation between renal size and body weight. It shows that the heavier the individual is, the bigger the size of the kidney will be. This goes the same for left and right kidneys. Similar findings were also reported on several separate studies such as a study done by Mario et al. in 2002 for Brazilian population as shown in Table 5.

The same goes with the individual's height which is presented in Table 3[1, 6]. When we look at the renal size for left and right kidneys in Table 3, there is increasing renal size correspondingly to the subject's height. Hence, we can conclude that there is a significant direct positive correlation between the renal size and the body height. This finding matches with the finding in Mario et al who had also created a table on renal dimensions according to the patient's height (Table 6).

Comparison between Malaysian and Brazilian's body weight in right and left kidney were shown in Figure 3 and 4. It can be seen clearly that with the same body weight, there is quite a big difference in the kidney size in both of the ethnicities. This goes the same to the body height which is shown in Figure 5 and 6. Still yet, the left kidney size is greater than the right kidney size for both of the ethnicities.

Table 4: Relationship between gender and renal dimensions in individual

Renal Dimensions	Gender	
	Male (n=376)	Female (n=269)
Right Kidney Length (cm)	12.03	12.01
Right Kidney Width (cm)	5.64	5.62
Left Kidney Length (cm)	12.67	12.59
Left Kidney Width (cm)	6.07	5.99
Right Kidney Area (cm^2)	53.40	53.16
Left Kidney Area (cm^2)	60.52	59.36

Table 5: Renal dimensions according to body weight

Body Weight (kg)		Length (cm)	
		Right*	Left*
<60 ;	n=216	11.6±0.7	12.2±0.7
60-69 ;	n=331	11.9±0.7	12.5±0.7
70-79 ;	n= 236	12.1±0.7	12.7±0.7
>80 ;	n= 121	12.5±0.8	13.2±0.8
*p<0.001 according to analysis of variance			

Table 6: Renal dimensions according to patient's height

Patient's Height (m)		Length (cm)	
		Right*	Left*
<1.55;	n=194	11.4±0.6	11.9±0.6
1.56- 1.65;	n=290	11.7±0.6	12.3±0.6
1.66-1.75;	n=332	12.3±0.7	12.9±0.7
1.76-1.85;	n=88	12.6±0.5	13.2±0.5
*p<0.001 according to analysis of variance			

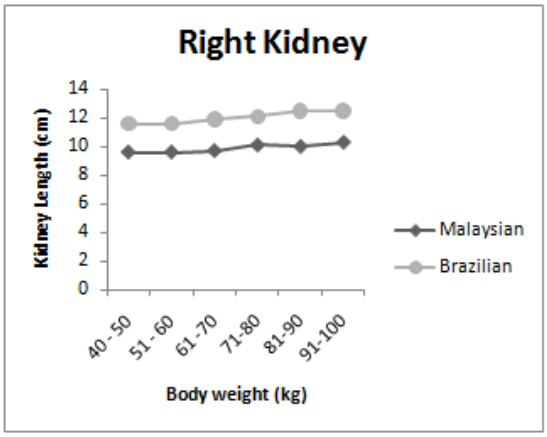

Figure 3: Comparison of Malaysian and Brazilian body weight in right kidney length

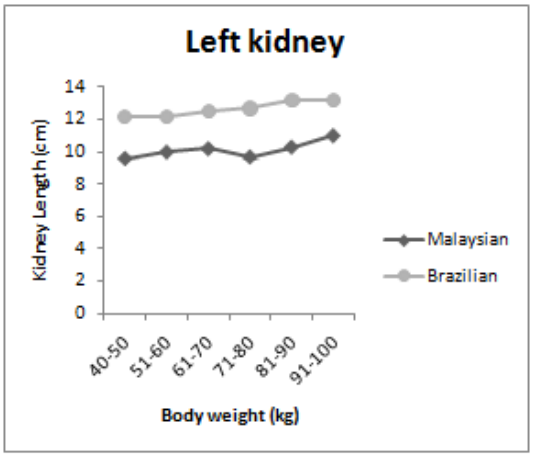

Figure 4: Comparison of Malaysian and Brazilian body weight in left kidney length

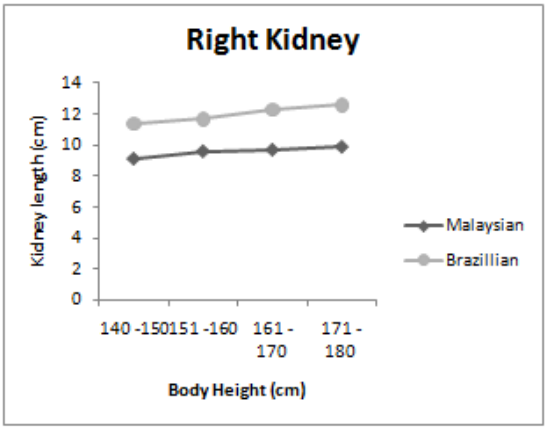

Figure 5: Comparison of Malaysian and Brazilian body height in right kidney

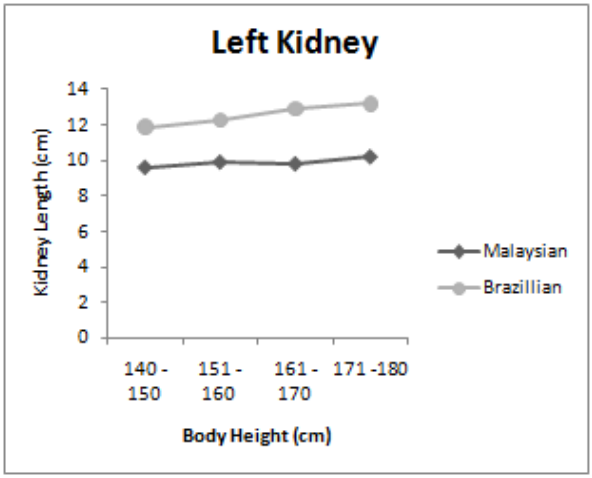

Figure 6: Comparison of Malaysian and Brazilian body height in left kidney

IV. DISCUSSIONS

Normal renal measurements are an important factor in studying renal function and its disorders. It is also important in making a primary diagnosis as well as during the subsequent follow-up of patients with renal diseases, in order to monitor the diseases' progress [5]. Ultrasound imaging has been a method of choice to evaluate these measurements due to its availability throughout the country. Although, there are some limitations such as variations in terms of observers' skills and interpretation, variability in patients' cooperation, position and hydration status, it is still widely used due to its non-invasiveness, reproducibility and accessibility [5].

In the present study, we analyzed renal size in terms of length, width, and thickness which are simple, reproducible, reliable and objective measurements [6]. Data that was obtained for both left and right kidney from all the participants of this research agreed with previous studies done that left kidney is larger than the right [6-8]. One possible explanation is, due to the size of spleen which is smaller than the liver, thus the left kidney has more space for its growth. Another possible explanation is that because of the left renal artery is shorter and straighter than the right one; this causes increased blood flow in the left artery which may result in relatively increased in volume [12, 13].

The present data show that weight and height of a person is directly proportional to the all parameters of the kidney measurements. The relation between body weight and height to kidney size also equals to other studies that the higher the body weight, the bigger the kidney is. This is independent of gender. The same goes to the height [6, 13]. Thus, heavier and taller individuals have longer, wider and thicker kidneys than their lighter counterparts [1]. This is most likely due to; the kidneys develop at the same rate as the whole body develops. From the data obtained, we can also conclude that renal size in female population is relatively smaller compared to male population. However, the differences in renal measurements found in this study are quite minimal.

A. Comparison with other study

Study done by Emamian et al.[21], based on Denmark population with 665 adult volunteers which consist of different ranged of age had shown that the median renal lengths were 11.2cm on the left side and 10.9cm on the right side. The mean renal volumes for the left kidney were 146cm^3 and 134cm^3 for the right kidney. As compared to our study, the mean renal length for Malaysian is 1.3cm on the left and 1.2cm on the right shorter than those who are from Denmark. For the renal volume, the Malaysian is having a smaller renal volume where the difference is 52.4cm^3 and 62.5cm^3 on the left and right respectively.

Another study from Mexican population by J. Oyuela-Carrasco et al.[25] had reported the renal length by ultrasound in 153 Mexican adults. The differences between Malaysian and Mexican in the whole group were 0.68 ± 1.71cm and 0.73 ±1.43cm on the left and right kidney respectively In the male category, the difference for left renal length was 0.67 ±1.57cm and 0.9 ±1.27cm for right renal length. In the female category, the differences were 0.66 ± 1.82cm and 0.5 ±1.52cm for left and right respectively. What we can say here is that all the differences show that Mexican has greater renal length than Malaysian.

Next, the results of this study were also compared with the study based on Caucasians population. The studies done by Mc Minn and Williams et.al. were compared with this study. From what we can conclude from the comparison was that Caucasian without doubt have larger renal size if compared to our population. The difference between our study and their studies can be seen obviously where their renal length are longer than ours to the maximum of 2cm.

Another comparison was made between Southeast Nigerians [22] and Malaysian population. The overall mean renal length in Nigeria for left kidney was 10.6cm and 10.3cm for the right kidney. If we look at the overall mean renal length of Malaysian in Table 1, our population is in fact shorter in renal length when compared to Nigerian Population.

Table 7(a): Comparison of renal parameters with other studies (Length & Width)

Authors	Ethnicity	N		Length(cm)			Width(cm)		
				All	Male	Female	All	Male	Female
Emamian et al	Danish	665	L	11.2	-	-	-	-	-
			R	10.9	-	-	-	-	-
J. Oyuela-Carrasco et al.	Mexican	153	L	10.5	10.7	10.4	-	-	-
			R	10.4	10.5	10.2	-	-	-
Okoye IJ et al	Nigerian	200	L	10.6	-	-	-	-	-
			R	10.3	-	-	-	-	-
D. Shani et al.	Northwest Indian		L	10.0	9.97	9.21	4.6	4.64	4.35
			R	9.9	9.95	9.13	4.6	4.58	4.46
Buchholz NP	Pakistani	194	L&R	10.4	-	-	4.5	-	-
Barton EN et al.	Jamaican	49	L	10	-	-	-	-	-
			R	9.7	-	-	-	-	-
McMinn	Caucasians			12	-	-	6	-	-
Williams et al.	Caucasians			-	11	-	-	6	-
Tanaka et al.	Japanese		L	-	11.5	11.4	-	5.7	5.2
			R	-	11.3	11.2	-	5.5	5.2
K.Y. Kang et.al	Korean	125		11.1	-	-	6.2	-	-

Table 7(b): Comparison of renal parameters with other studies (thickness & volume)

Authors	Population	N		Thickness (cm)			Volume		
				All	Male	Female	All	Male	Female
Emamian et al	Danish	665	L	-	-	-	146	-	-
			R	-	-	-	134	-	-
J. Oyuela-Carrasco et al.	Mexican	153	L	-	-	-	-	-	-
			R	-	-	-	-	-	-
Okoye IJ et al	Nigerian	200	L	-	-	-	-	-	-
			R	-	-	-	-	-	-
D. Shani et al.	Northwest Indian		L	3.4	3.4	3.11	-	-	-
			R	3.3	3.33	3.12	-	-	-
Buchholz NP	Pakistani	194	L&R	-	-	-	-	-	-
Barton EN et al.	Jamaican	49	L	-	-	-	-	-	-
			R	-	-	-	-	-	-
McMinn	Caucasians			3	-	-	-	-	-
Williams et al.	Caucasians			-	3	-	130	-	-
Tanaka et al.	Japanese		L	-	3.5	3.1	-	-	-
			R	-	3.2	3.0	-	-	-
K.Y.Kang et al.	Korean	125		4.73	-	-	158	-	-

D. Shani et al [26] had conducted a study on Northwest Indian population. The measurement of length, width, and thickness of kidney in both male and female groups are reported in the study. Again, comparison were made and unexpectedly found out that, the renal size of Indian population is relatively similar to the Malaysian. In this study, we found out that the kidney of Malaysian is slightly thicker than the Indian in both male and female categories.

It is rather unfair if we do not compare our study with the Asian around us. Therefore, we put side by side our study with the study done by K.Y.Kang et al [32] where the study is conducted on Korean population. As we can see from table 7, the Korean has a longer, wider and thicker kidney than ours. It is a surprise that the Korean is having a larger renal size. Therefore, we deepen our analysis by comparing the average weight for both studies. The average weight for K.Y.Kang et al. was 63kg whereas the average weight for this study was 57kg. The average body weight for K.Y.Kang et.al. is higher than this study. This goes the same to the height of both studies. The Korean has higher mean height with 166cm when compared to this study with only 163cm. According to Theodore E et al. [33]., the normal kidney size is related closely to the body height. This result showed that we cannot use the same nomogram onto different populations since we are from different ethnicities even though we are from the same country.

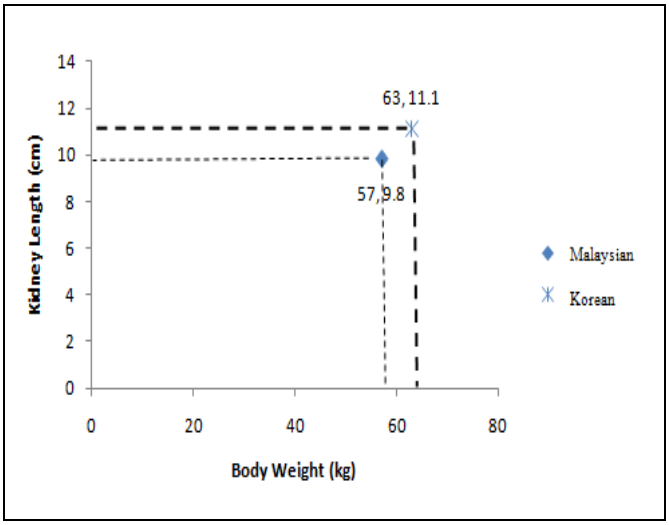

Figure 7: Comparison of the average weight of Korean and Malaysian studies.

When taking into consideration the comparisons that had been done among several populations, most of the comparisons reflect on the shortness of renal length in Malaysian. This could be explained with the physical size of Asian itself. Study done by Mario et al. in 2002 and one other study done in Pakistan [1] highlights the necessity of investigating renal dimensions for each population, strengthening that European and American populations' data cannot be used as universal patterns [6] as it is known that the Westerners are taller and bigger compared to other ethnics such as Asians. It has been a fact that our organs develop together with the body. It is no doubt that the organ size is related closely to the body size.

On the other hand, O.Bircan et. al. [24] who had done a similar study proved that the Hudson's equation is not able to estimate the kidney length of their (Turkish) population accurately. The study strongly emphasized that the European data should not be used in their clinics. In addition, the study had also pointed out that the shortness of the renal length in their population may provide wrong interpretation to the clinician since the pathological conditions have given significant effect on the kidney size. It is demonstrated that the standard which is based on Caucasian data is no longer suitable for universal indication

Thefore, more studies on this issue should be conducted for each different population so that, in the near future there will be more accurate reference depending on each particular ethnic race. There are a few things that should be taking into account in the process of constructing and developing the normal renal standard or nomogram.

First of all, the sample size must be large enough to detect the clinically important effects [27]. If the sample size is too small, there is a high possibility to have a false-negative finding. Nevertheless, study with an overlarge sample should not be conducted as it seems unethical to involve unnecessary extra subjects and correspondingly increased costs [28].

Next, the subjects for the study should at least stay in Malaysia for 10 years and above. This is related closely to not only the genetic variation but also the human geographic variability. The environment, nutrition and diet intake of one population may affect the growth rates of one population. The growth rate corresponds with the weight and height of an individual. Molecular biologist, Chao-Qiang Lai had stated that different genetic background of ethnic groups and the distinct environments (climates, dietary habits and lifestyle) they experience are the main reason for such diversities in height heritability. Since Malaysia is a multiracial country, the subjects should include Malay, Chinese, Indian, Punjabi, Indigenous Sarawakian, Indigenous Sabahan, and Orang Asli each in a reasonable portion.

Besides, the volunteers who agree to join the study should be free from any chronic disease. It is advised to perform the ultrasound screening by a single observer and machine to avoid inter-observer variability. The above mentioned aspects are recommended to create and develop a more reliable and accurate benchmark parameters for our population.

V. Conclusion

In this study, renal size among different ethnicities for example Malaysian, Brazilian, Pakistani, Korean, Indian, Caucasians etc have been compared. Age, weight and height are also taken into account in this study. The study is done with ultrasound machine among malaysian population and compare with other studies. The result shows that the renal size is different among different ethnicities.

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REFERENCES

[1] Buchholz NP, Abbas F, Biyabani SR, Afzal M, Javed Q, Rizvi I, et al., 2000. Ultrasonographic renal size in individuals without known renal disease. J. Pak Med Assoc. 50: 12-16.

[2] Elkin M, 1980. Kidney size, In: Elkin M (ed.), Radiology of the urinary system. Boston, Little, Brown and company: 1014-1032.

[3] J.J. Chen, Jizu Zhi, Wenyang Mao and G.F. Steinhardt, 2006. MrNomogram: A web-based multivariable pediatric renal nomogram. Journal of Paediatric Radiology.Vol. 2 (5): 436-438.

[4] J.J. Chen, J. Pugach, M. Patel, A. Luisiri and G.F. Steinhardt, 2002. The renal length nomogram: a multivariate approach. J Urology. Vol. 168: 2149-2152

[5] J.M. Zerin and C.E. Blane, 1994. Sonographic evaluation of renal length in children: a reappraisal. Pediatric Radiology. Vol. 24: 101-106.

[6] Justo Oyuela-Carrasco, Franciso Rodriguez-Castellanos, Eric Kimura, \ Rosa Elena Delgado, Juan Pablo Herrera-Felix, 2009. Renal length by ultrasound in Mexican adults. Nefrologia. 29(1): 30-34.

[7] Mário M. R. Fernandes, Carla C.S.Lemos, Guilherme S. Lopes, Eugenio P. Q. Madeira, Omar R. Santos, David Dorigo, Raquel Bregman, 2002. Normal renal dimensions in a specific population. International Braz J Urol.Vol. 28 (6): 510-515.

[8] Mazzotta L, Sarteschi LM, Carlini A, Antonelli A., 2002. Comparison of renal ultrasonographic and functional biometry in healthy patients and in patients with chronic renal failure. Arch Ital Urol Androl. 74(4): 206-209.

[9] Odita JC, 1982. Roentgenologic estimation of kidney in adult Nigerians. Trop Geogr Med. 34: 177-181.

[10] Ohikhokhai WI, Ogbeide OU, Akhigbe A., 2010. Effect of patient height and weight on sonographically measured renal sizes in a sample of Nigerian adults without known renal disease. Pak J Med Sci. 26(4): 914-917.

[11] Sampaio FJ, Mandarin-de-Lacerda CA, 1989. Morphometry of the kidney. Applied study in urology and imaging. J Urol. [Paris]. 95: 77-80.

[12] Seyed Alireza Emamian, Michael Bachmann Nielsen, Jan Fog Pedersen, Lars Ytte, 1993. Kidney dimensions at sonography: Correlation with age, sex and habitus in 665 adult volunteers. AJR. 160: 83-86.

[13] Wing Hang Luk, Adrian Xu Ning Lo, Andrea Wai San Au-Yeung, Karen Ka Yee Liu, Yip Hin Woo, Chilene Chi Lin Chiang, Kitty Kit Lin Lo, 2010. Renal length nomogram in Hong Kong Asian children: sonographic measurement and multivariable approach. Journal of Paedaitrics & Child Health. Vol. 46 (6): 310-315.

[14] E. Supriyanto, Hafizah W.M, Wui Y.J, Arooj A. Automatic Non Invasive Kidney Volume Measurement Based On Ultrasound Image Proceedings of 15th International WSEAS GSCC Multiconferences held in Corfu Island , Greece, July 14- 16,2011 ISBN: 978-1-61804-019-0 Page 387-392

[15] E. Supriyanto., Nurul A.T., Syed M.N., Automatic Ultrasound Kidney's Centroid Detection System, 15th International WSEAS GSCC Multiconferences held in Corfu Island, Greece, July 14-16, 2011 ISBN: 978-1-61804-019-0 Page 160-16

[16] Wee L.K., E. Supriyanto, Automatic Detection of fetal Nasal Bone in 2 dimensional Ultrasound Image Using Map Matching, 12th WSEAS International Conference on Automatic Control, Modeling & Simulation, 2010, pp. 305-309.

[17] E. Supriyanto., Wee L.K., Min T.Y., Ultrasonic Marker Pattern Recognition and Measurement Using Artificial Neural Network, 9th WSEAS International Conference on Signal Processing, 2010, pp. 35-40

[18] Wee L.K., Arooj A., E. Supriyanto, Computerized Automatic Nasal Bone Detection based on Ultrasound Fetal Images Using Cross Correlation Techniques, WSEAS Transactions on Information Science and Applications, Vol. 7, No. 8, 2010, pp.1068-1077.

[19] L.K. Wee, E. Supriyanto, Nuchal Translucency Marker Detection Based on Artificial Neural Network and Measurement via Bidirectional Iteration Forward Propagation, WSEAS Transactions on Information Science and Applications, Vol. 7, No. 8, pp.1025-1036.

[20] Geelhoed, J. J. M., Kleyburg-Linkers, V. E., Snijders, S. P. E., Lequin, M., Nauta, J., Steegers, E. A. P., Van Der Heijden, A. J., et al. (2009). Reliability of renal ultrasound measurements in children. Pediatric nephrology Berlin Germany,24(7), 1345-1353. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19280227

[21] Emamian SA, Nielsen MB, Pedersen JF, Ytte L. Kidney dimensions at sonography: Correlation with age, sex and habitus in 665 adult volunteers. AJR Am J Roentgenol 1993;160:83-6.

[22] Okoye I.J., Aqwu K.K, Indigo FU. Normal sonographic renal length in adult southeast Nigerians. Afr J Med Med Sci.2005 Jun; 34(2):129-31

[23] Barton EN, West WM, Sargeant LA, Lindo JF, Iheonunekwu NC, A sonographic study of kidney dimensions in a sample of healthy Jamaicans. West Indian Med J. 2000 Jun; 49(2):154-7.

[24] Bircan O., Oner G., Saka O., Kavasoglu T., Akaydin M., The estimation of kidney sizes in Turkish population. Journal of Islamic Academy of Sciences 1993,6:3, 197-201

[25] J. Oyuela-Carrasco, F. Rodriguez-Castellanos, E. Kimura, R. Delgado-Hernandez, J.P. Herrera-Felix. Renal length by ultrasound in Mexican adults. Nefrologia 20009;29(1):30-34

[26] D. Shani, I. Jit, L. Sodhi, Weight and Measurements of kidneys in Northwest Indian adults. American Journal of Human Biology 2001, 13:726-732.

[27] Altman D.G., Statistics and ethics in medical research :III how large a sample? British Medical Journal. 1980 November 15; 281(6251): 1336-1338.

[28] Kirby A., Gebski V., Keech A.C., Determining the sample size in a clinical trial. MJA 2002 177(5):256-257.

[29] McMinn RMH. 1994. Last's anatomy, regional and applied, 9th edition. Edinburgh : Churchill Livingstone

[30] Tanaka G, Nakahara Y, Nakazima Y. 1989. Japanese Reference Man 1988 – 1V studies on the weight and size of internal organs of normal Japanese. Nippon Acta Radiol 49 :344-364.

[31] Williams PL, Bannister LH, Berry MM, Collins P, Dyson M, Dussek JE, Ferguson MWJ. 1995. Gray's Anatomy, 38th edition. London :Churchill Livingston.

[32] Kang K.Y, Lee Y.J, Park S.C., Yang C.W., Kim Y.S., Moon I.S., Koh Y.B., Bang B.K., Choi B.S. A comparative study of methods of estimating kidney length in kidney transplantation donors. Nephrol Dial transplant (2007) 22 : 2322-2327.

[33] Pascal G.B., Theodore E. The roentgenographic determination of

normal adult kidney size as related to verterbal height. Ajr vol 116, no 4.

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