

Ultrasonographic Renal size in Individuals without known Renal Disease

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Abstract

Objective: In order to establish some preliminary data of our population, we determined the ultrasonographic kidney dimensions in individuals without known renal disease. We assessed whether age, sex, side, body mass index (BMI) and presence or absence of diabetes mellitus and hypertension affect the renal size.

Methods: Ultrasonographic kidney measurements were performed on 194 adult patients without known kidney lesions. Measurements included length, width, cortical thickness and estimation of renal size which was obtained by multiplying the first three variables. The effect of age, gender, side, height, weight, BMI, hypertension and diabetes mellitus was statistically analyzed.

Results: The mean kidney length was 10.4 ± 0.8 cm, mean width 4.5 ± 0.6 cm and mean cortical thickness 1.6 ± 0.2 cm. The estimated mean renal size was 76 ± 22 cm³. Kidney length did not significantly differ between right and left, however, kidney width, cortical thickness and size did ($p < 0.05$). Right kidneys were smaller than the left ones. In univariate analysis, the mean renal size correlated with age, sex, side, BMI and absence or presence of hypertension and diabetes mellitus. In a multivariate analysis, however, the only significant factors affecting renal size were sex and BMI.

Conclusion: We conclude that renal size is related to age, side, sex and the individual's height and weight. The normal values for the Pakistani population. Population-based studies are needed to establish (JPMA 50:12, 2000).

Introduction

The kidney size of a patient is a valuable diagnostic parameter in urological and nephrologic practice. While the leading anatomy text describes the adult kidney as 12 cm long, 6 cm wide and 3 cm deep¹, further review of the literature shows that renal size varies with age, gender, body mass index, pregnancy and co-morbid conditions^{2,3}. Renal size may be an indicator for the loss of kidney mass and therefore, kidney function^{2,3}. It is valuable in monitoring unilateral kidney disease through comparison with the other, compensatorily increased side⁴ and for the discrimination between upper and lower urinary tract infections⁹. Renal infections/inflammations, nephrologic disorders, diabetes mellitus and hypertension are the most important co-morbid conditions affecting renal size^{4-9,5,16}. Since the renal size is affected by various factors, it is necessary to first establish the normal values. The information available in the West may not be extrapolated to our population since the renal size may differ between ethnic groups and according to body size^{11,17-19}. While population-based studies are needed to establish the normal values for Pakistani individuals, in our study we determined the ultrasonographic renal size in a group of individuals with no known renal disease and assessed the effect of age, gender, side and BMI. In addition, we assessed the effects of hypertension and diabetes mellitus in a subgroup of our patients on renal size and compared our findings with the literature.

Subjects and Methods

For this prospective study, 201 consecutive patients between 13 to 80 years of age. who underwent an abdominal diagnostic ultrasound at the Department of Radiology of the Aga Khan University Hospital, Karachi between August 1997 and March 1998, had an additional screening and measurements of the kidneys. Pregnant patients, patients with known kidney or urinary stone diseases and patients with an ultrasound for the diagnosis of lumbar or urinary symptoms were excluded. Seven additional patients were excluded due to incomplete data to leave 194 study patients.

The kidney dimensions measured include length (distance pole to pole), width (transversal axis) and cortical thickness, in millimeters. We estimated the kidney size, defined as length x width x cortical thickness, which correlates closely to the renal volume. All ultrasounds were performed by one experienced radiologist to exclude inter-observer variation. Additional data recorded either at presentation or at subsequent telephonic contact include age, gender, height, weight, BMI (weight [kg]/height [meter²]) and history of established hypertension and diabetes mellitus. Data were entered in a Microsoft ExcelR database and statistically analyses using SPSS Version-8. Comparative analyses were done by means of a student's "t" test. A p-value <0.05 was regarded as statistically significant.

Results

Of the total 194 patients, 98 were males and 96 females. The mean age was 44.7 ± 14 years (range 13-80); 46.1 ± 15.4 years (13-80) for males and 43.3 ± 13.2 years (15-80) for females.

Renal size and effect of gender and side: The mean kidney length was 10.4 ± 0.8 cm (7.9 - 12.3), the mean kidney width 4.5 ± 0.6 cm (3.3 - 6.3) and the mean cortical thickness 1.6 ± 0.2 cm (1 - 2.0).

Kidney size (length x width x cortical thickness) was 76.16 ± 21.7 cm³ (36.8 - 138).

There was no significant difference in kidney length between right and left side ($P < 0.06$). However; differences in width, cortical thickness and size were all significant ($P < 0.05$), with the right kidney being significantly smaller than the left (Table 1).

Table 1. Ultrasonographic kidney measurements and side differences in the whole study population (n=194).

Measurements	Right kidney (Mean±SD)	Left kidney (Mean±SD)	P value
Length (cm)	10.4 ± 0.9	10.5 ± 0.9	0.469
Width (cm)	4.2 ± 0.7	4.8 ± 0.7	<0.001
Cortical thickness (cm)	1.5 ± 0.2	1.6 ± 0.2	<0.001
Size (cm ³)	70 ± 22	82 ± 24	<0.001

As a group, female kidneys were significantly smaller than the male kidneys (Table 2).

Table 2. Ultrasonographic kidney measurements by side and gender.

Measurements	Males (n=98) Mean±SD	Females (n=96) Mean±SD	p value
Length (cm)			
Right	10.6±0.9	10.3±0.9	0.037
Left	10.6±0.9	10.3±0.9	0.024
Width (cm)			
Right	4.5±0.7	4.0±0.6	0.000
Left	5.0±0.8	4.6±0.6	0.000
Cortical thickness (cm)			
Right	1.6±0.2	1.5±0.2	0.002
Left	1.7±0.2	1.5±0.2	0.000
Size (cm ³)			
Right	77±22.6	63±18.1	0.000
Left	90±25.7	74±20.3	0.000

Renal size and effect of age: In our study, there were 9 individuals in their 2nd decade of life, 23 in the 3rd, 48 in the 4th, 52 in the 5th, 32 in the 6th, 22 in the 7th and 8 in the 8th decade of life. All renal dimensions increased with age till the 3rd decade, remained more or less stable through the middle age, then declined beyond the 6th decade (Table 3; Figure 1).

Table 3. Ultrasonographic determination of renal size according to age.

Age in Years	Righth kidney (Mean±SD)				Left kidney (Mean±SD)			
	Length (cm)	Width (cm)	Thickness (cm)	Size (cm ³)	Length (cm)	Width (cm)	Thickness (cm)	Size (cm ³)
11-20 (9)	10.0±0.8	4.4±0.6	1.6±0.2	64±17	10.2±0.8	4.6±0.4	1.6±0.2	77±17
21-30 (23)	10.3±0.6	4.3±0.8	1.6±0.2	72±21	10.4±0.7	4.7±0.5	1.7±0.2	83±19
31-40 (48)	10.6±1.0	4.3±0.7	1.5±0.2	70±21	10.6±0.9	4.9±0.7	1.6±0.2	83±24
41-50 (52)	10.6±0.8	4.2±0.7	1.6±0.2	70±22	10.5±0.8	4.7±0.7	1.6±0.2	82±23
51-60 (32)	10.5±1.1	4.3±0.6	1.6±0.2	72±23	10.7±1.2	4.7±0.9	1.6±0.3	84±33
61-70 (22)	10.1±0.9	4.3±0.8	1.6±0.2	70±24	10.3±1.1	4.9±0.7	1.6±0.2	84±24
71-80 (8)	9.9±0.7	4.2±0.6	1.4±0.2	60±19	9.5±0.6	4.6±0.5	1.5±0.3	69±23

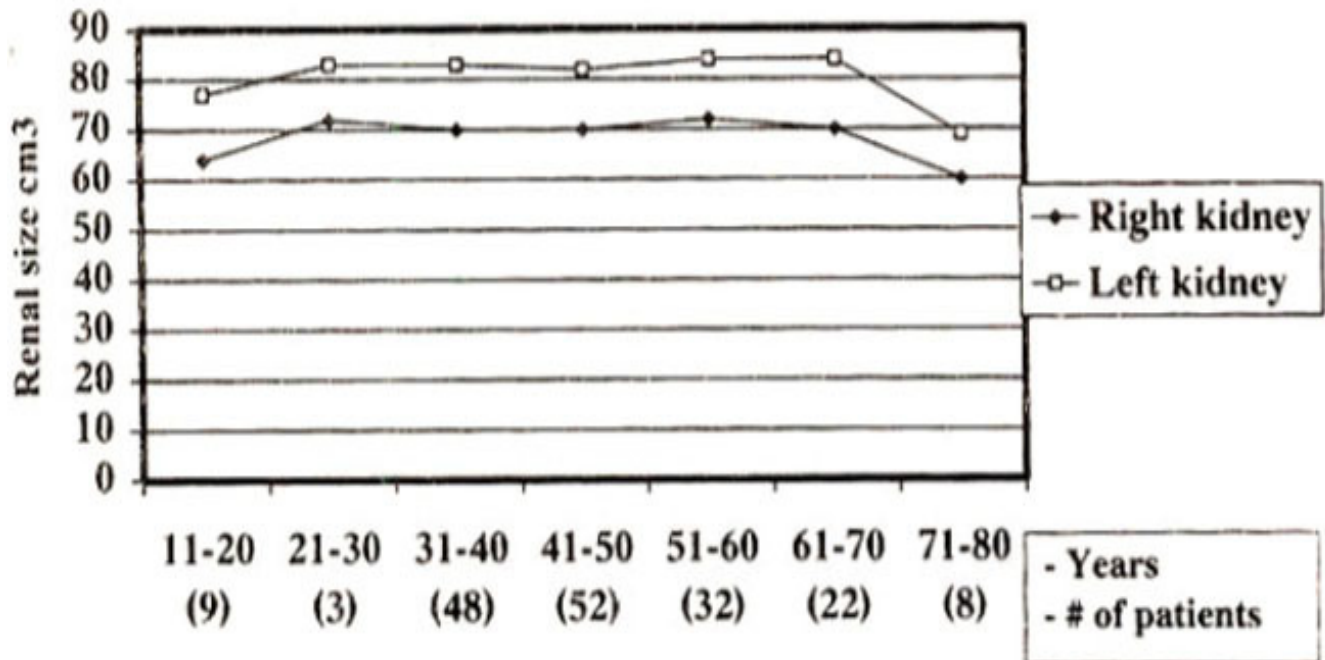


Figure 1. Changes in dimensions of renal size

Renal size and effect of body mass index:

Information on body mass index (BMI) (weight [meter]²) was available in 118 study patients who were then divided into 3 groups, i.e., BMI 10-20, 21-30 and 31-40. The mean renal size correlated well with BMI and correspondingly increased with BMI. This observation, however, was not made for the right kidney in the 31-40 BMI group (Figure 2).

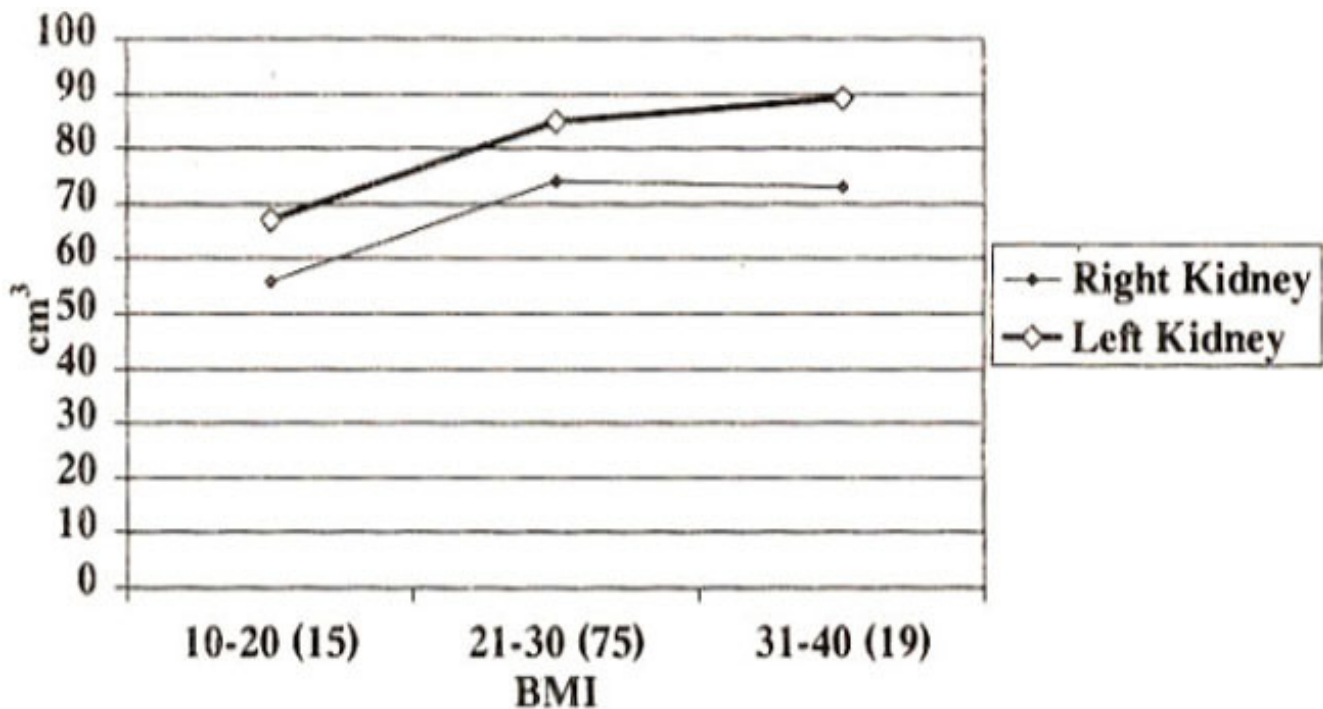


Figure 2. Correlation of renal size with BMI

Renal size in hypertensives versus non-hypertensives and diabetics versus non-diabetics: Information about the absence or presence of established hypertension or diabetes mellitus was available in 118 individuals.

Table 4. The effect of hypertension and diabetes mellitus on renal size in 118 individuals.

	HTN (n=22)	Non-HTN (n=96)	P value	Diabetics (n=14)	Non-Diabetics (n=104)	p value
	Mean±SD	Mean±SD	Mean±SD	Mean±SD		
Right kidney	66.3±21.0	71.8±23.7	0.295	81.2±29.7	69.4±22.1	0.07
Left kidney	81.2±25.1	83.4±25.7	0.717	91.52±26.9	81.9±25.2	0.18

HTN = Hypertensives

Non-HTN = Non-hypertensives

Table 4 shows that the mean renal size in both sides was smaller in hypertensive individuals when compared with non-hypertensives, but the difference was statistically insignificant. Similarly, diabetics had larger kidneys than non-diabetics, but the difference was insignificant. Since BMI could be an important confounding factor in this analysis, we compared the groups again in BMI matched individuals (Table 5)

Table 5. The effect of hypertension and diabetes mellitus on renal size in body mass index matched individuals.

	HTN (n=21) Mean±SD	Non-HTN (n=21) Mean±SD	p value Mean±SD	Diabetics (n=10) Mean±SD	Non-Diabetics (n=10)	p value
Right kidney	67.6±20.7	80.0±26.1	0.020	89.19±28.1	63.92±25.2	0.006
Left kidney	82.6±24.8	88.8±30.5	0.255	96.5±24.7	73.3±20.7	0.013

HTN = Hypertensives

Non-HTN = Non-hypertensives

and except for the left kidney dimensions in hypertensive versus non-hypertensive individuals, the hypertensive kidneys were smaller and diabetic kidneys were larger.

Multivariate Analysis: We finally performed a linear regression analysis to assess the effect of the variables studied on renal size. Only BMI and sex of the individual independently influenced the kidney size on both sides. Both, hypertension and diabetes mellitus, which on univariate analysis had shown significant influence on renal size, were non-significant in the multivariate analysis (Table 6).

Table 6. Multivariate analysis of variables affecting renal size.

Variable	P value	
	Right kidney	Left kidney
Age	0.500	0.908
Body Mass Index	0.004*	0.001*
Sex	0.000*	0.000*
Hypertension	0.262	0.567
Diabetes mellitus	0.085	0.298

* Statistically significant.

Discussion

The normal size of a kidney is variable and is affected by age, gender, BMI, as well as the side. The size provides a rough indication of the renal function. The minimal size of a fully functional kidney is 9 cm in length². Decrease of size and function are seen with chronic renal failure⁴, renal arterial occlusion² and late stage renal venous thrombosis⁵. However, although kidney size seems to be related to a number of vascular diseases, there is no correlation with blood pressure²⁰. Physiologically, renal length decreases 0.5 cm per decade after middle age¹¹⁻³.

On the other hand, there is an increase in kidney size in early stage renal thrombosis⁵, early stage

diabetes mellitus^{7,8} and renal inflammation⁶. A physiological increase of glomerular filtration rate and kidney size can be observed in pregnancy¹⁰. Kidney size also increases with increased protein intake in mice²¹.

In order to estimate aberrations of kidney size, normal values must be established first. Not many studies have been done on this issue. There are, as far as we know, no reliable reference tables because the measurements vary between men and women, between people of different ethnic backgrounds and even between kidneys of the same individual. Also, it has to be borne in mind that kidney size measurements with ultrasound (US), as well as with CT and MRI result in a 24% underestimation of the renal value²².

Commonly, US is used to screen and measure the kidney. In comparison with an intravenous pyelogram, US is more accurate and suffers neither from the geometric magnification of X-raying, nor from a possible increase in kidney size by osmotic diuresis through iodinated contrast material²³. It has been analyzed as a reliable, repeatable (inter-observer variation) and reproducible (intra-observer variation) method²⁴. In our study, a single senior radiologist carried out the measurements at predetermined fixed points, to minimize the inter-observer and intra-observer variation. Studies on kidney length and size have also been made by means of CT²⁵ and MRI²². But although these methods show, not unexpectedly, a better repeatability²², we believe that US is the tool of first choice due to its ubiquitous availability, its easy handling and its cost-effectiveness.

Most studies have looked at kidney length. Ultrasonic kidney length measurement (bi-polar measurement) is the most commonly used and most practical measurement in clinical practice¹⁰ and is correlated to renal function³.

Normal renal length varies from 100 to 124 mm in different populations^{17-19,25} dependent on ethnic background, side and sex. While population-based studies are needed to establish the normal values for Pakistani individuals, our pilot study group showed a mean kidney length of 104 mm. This is at the lower end of the scale and together with a Malaysian study population¹⁹ is probably a reflection of the relatively small body size of most IndoAsians. Organ size is unquestionably related to the body size.

Accordingly, Africans figured in the upper range 17 and Caucasians somewhere in the middle²⁵.

In our study, the kidney length, width, cortical thickness and size were significantly larger in males than in females. This has been reported by other investigators^{17,19,26} and has been related to differences in body size²⁶. We found this difference significant even in the multivariate analysis.

Throughout all studies, there is a marked but not significant difference of kidney length between the right and left side, with the left side being on an average 5% larger^{11,17,19}. We feel it could be related to the hepatic mass which does not allow comparable vertical growth of the right kidney to that which is attained by the left kidney. In our study, except for the length, all other renal dimensions were significantly larger on the left than on the right side. We thus feel that instead of renal length the renal size as determined by us, or volume as assessed by others, may be used as the most useful parameter for evaluation and comparison.

The age of an individual has an important bearing on the kidney size. We found that the kidney size increases till the 3rd decade, remains stable through the middle age and then declines. We have developed a prototype reference table of age and renal dimensions for both sides, as there is no such information available for our population. The validity of this information, however, needs to be established through larger, population-based studies. Such a reference table is extremely useful for routine evaluations and monitoring of urological and nephrologic diseases.

Our data shows a strong correlation between renal size and BMI (Figure 2). The renal size increased correspondingly with an increasing BMI, except for the right kidney in the group of obese individuals (BMI:3 1-40). In these patients, the body mass increase may surpass the renal growth capacity. Also, it

has to be considered that gross obesity can be one of the limitations of ultrasound examination. Other investigators have also shown a strong correlation of renal volume with height, weight and BMI^{11,13,17,19}

We assessed the effect of hypertension and diabetes mellitus on renal size because of the frequent affection of our adult population with these co-morbid conditions. While in the univariate analysis, both hypertension and diabetes mellitus were significant factors affecting renal size, their effect was not significant in multivariate analysis. It has previously been shown that high blood pressure is not proportionally related to kidney size²⁰. In long-standing hypertension, however, the kidney size is shown to decrease due to ischemic changes with resultant fibrosis and hyalinization²⁷. Other investigators have related an increase in kidney size with an increased glomerular filtration rate in early stage diabetes mellitus. This increase represents indeed a risk factor for diabetogenic nephropathy thus making ultrasonic kidney measurement a tool for the diagnostic and prognostic assessment of diabetic patients^{7,8}.

Finally, of all the variables assessed in our study, the most significant factors associated with the kidney size were sex ($p=0.000$) and BMI ($p=0.01, 0.004$) in the linear regression analysis model.

In summary, normal values for kidney measurements are dependent on age, sex and body mass index. This has to be considered by the ultrasonographer. Aberrations from these values can give valuable general clues and confirmations in the diagnosis of particular diseases. A slightly small right kidney may be considered as normal and a reference table as developed by us can be used for routine evaluation. For the Pakistani population, normal kidney measurement values need to be developed by means of population-based studies.

Reference

1. Grays Anatomy. 38th ed, U.K. Churchill Livingstone, 1995.
2. Shcherbak AI. Angiographic criteria in the determination of indications for organ preserving surgery in renal artery occlusion. *Klin. Khir.*, 1989; 2: 5
3. Guzman RP, Zierler RE, Isaacson JA, et al: Renal atrophy and arterial stenosis. A prospective study with duplex ultrasound. *Hypertension*. 1994;23:346-47.
4. Yamaguchi S, Fujii H, Kaneko S. et al. Ultrasonographic study in patients with chronic renal failure. Part 1. Ultrasonic measurement of renal size and analysis of renal ultrasonotomograms. *Nippon Hinyokika Gakkai Zasshi*, 1990;81: 1175-77.
5. Montague JP, Neuenschwander S, Duguet-Lannes MD, et al. Renal venous thrombosis in infants. Ultrasonic findings in 7 cases. *Arch. Fr. Pediatr.*, 1982;39:67-68.
6. Hiraoka M, Itono C, Ssuchida S, et al. Ultrasonographic findings of acute tubulointerstitial nephritis. *Am. J. Nephrol.*, 1996;16:154.
7. Tuttle KR, Bruton JL, Perusek MC. et al. Effect of strict glycemic control on renal hemodynamic response to amino acids and renal enlargement in insulin-dependent diabetes mellitus. *N. Engl. J. Med.*, 1991;324:1626-29.
8. Schwieger J, Fine LG. Renal hypertrophy. growth factors and nephropathy in diabetes mellitus *Semin. Nephrol.*, 1990;10:242-43.
9. Dinkel E, Ortit S, Dittrich M, et al. Renal sonography in the differentiation of upper front lower urinary tract infection. *Am. J. Roentgenol.* 1986; 146:775-777.
10. Christensen T, Klebe JG, Bertelsen V. et al. Changes in renal volume during normal pregnancy. *Acta. Obstet. Gynecol. Scand.*, 1989;68:541-43.
11. Emamian Sa, Nielsen MB, Pedersen IF, et al. Kidney dimensions at sonography. Correlation with age, sex and habitus in 665 adults volunteers. *Am. J. Roentgenol.*, 1993;160:83-84.
12. Meyer BR. Renal function in aging. *J. Am. Geriatr. Soc.* 1989;37:791-92.

13. McLachlan M, Wasserman P. Changes in sizes and distensibility of the aging kidney: *Br. J. Radiol.*, 1981;54:488.
14. Josephson S, Larsoon F. Experimental partial ureteric obstruction in newborn rats. VIII. Contralateral kidney weight after release of the obstruction. *Urol. Int.*, 1996;57: 135-37.
15. Paivansato-MJ, Merikanto-J., Savolainen-M.I et al. Effect of hypertension, diabetes and other cardiovascular risk factors on kidney size in middle aged adults. *Clin Nephrol.*, 1998;50: 161-68.
16. Yamada-H, Hishida-A, Kumagai-H. et al. Effects of age, renal diseases and diabetes mellitus on the renal size reduction accompanied by the decrease of renal function. *Nippon-Jinzo-Gakkai-Shi.*, 1992;34:1071-75.
17. Odita JC, Ugbo-daga CI. Roentgenologic estimation of kidney size in adult Nigerians. *Trop. Geogr. Med.*, 1982;34: 177-79.
18. Sainpaio EJ, Mandarun de Lacerda Ca, Morphometry of the kidney. Applied study in urology and imaging. *J. Urol. Paris.* 1989;95:77-78.
19. Wang F, Cheok SP, Kuan BB. Renal size in healthy Malaysian adults by ultrasonography. *Med. J. Malaysia*, 1989;44:45-46.
20. Raunan GV, Clark A, Campbell S. et al. Is blood pressure related to kidney size and shape? *Nephrol. Dial. Transplant*, 1998;13 728.
21. Hammond KA, lanes DN. The effect of increased protein intake on kidney size and function. *J. Exp. Biol.* 1998;211:2081-82.
22. Bakker J, Olree M, Kaatee R. et al. In vitro measurement of kidney size. Comparison of ultrasonography and MRI. *ultrasound Med. Biol.*, 1998;24:683-84.
23. Brandt TD, Neiman HL, Dragowski Mi. et al. Ultrasound assessment of normal renal dimensions. *J. Ultrasound Med.*, 1982;1:49-51.
24. Ablett MJ, Coulthard A, Lee RE, et al. How reliable are ultrasound measurements of renal length in adults? *Br. J. Radiol.*, 1995;68:1087-89.
25. Gremigni D, Todescan GC, Giannardi G, et al. Renal volume and human somatic type. *Boll Soc. Ital. Biol, Sper.*, 1984;60:887-88.
26. Miletic D, Fuckar S, Stistic A, et al, Sonographic measurement of absolute and relative renal length in adults. *J. Clin. Ultrasound.* 1998;26:185-87.
27. Rasmussen SN, Haase L, Kjeldsen H, et al. Determination of renal volume by ultrasound scanning. *J. Clin. Ultrasound.*, 1978;6: 160-63.