NORMAL VARIANCE IN ULTRASOUND MEASURED RENAL DIMENSIONS WITH AGE, SEX AND BODY HABITUS IN A SPECIFIC POPULATION WITHOUT KNOWN RENAL DISEASE

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ABSTRACT

Introduction: Evaluation and follow-up of patients with renal diseases is commonly done by renal ultrasonography. Renal size is influenced by some factors such as age, height, weight, body mass index and ethnicity. The aim of this study was to evaluate the normal range of dimensions of kidney, like length, width, thickness & volume and its correlation with age, sex, height, weight and body mass index in population of eastern Odisha by Ultrasonography.

Material & Methods: Ultrasound was performed on 223 subjects. Initially the image was taken in supine and later in both lateral decubitus position. The measurements of kidney were taken from the freezed images in longitudinal axis and the transverse section obtained at the level of the renal hilum.

Results: In 63.68% cases the kidney length and in 81.17% cases, the kidney volume was larger on left side. A decline trend in all the measurements of parameters beyond 50 years was observed in the present study. However, the mean volume on both sides had a slight increasing trend in 61-70 years age group.

Keywords: Renal Ultrasonography, renal size, body mass index, kidney volume,

INTRODUCTION

The kidneys, one of the essential organs of body are part of the urinary system. It excrete the metabolic waste by filtering the plasma of the blood [1]. Renal function has close relation with renal size. Nephrological disorders like renal infections, inflammation and co-morbid conditions like hypertension and diabetes mellitus affect the renal size [2-5]. Chronic kidney diseases, renal growth, cysts can be associated with change in size and shape of kidney. Thus, it is imperative to establish the pattern of normal renal dimensions. Kidney volume is regarded as the most precise indicator of kidney size, which correlates best with the subject's height, weight and total body area [6,7]. Renal ultrasonography is currently used for the evaluation and follow-up of patients with renal diseases, which is a relatively

inexpensive, quick, non-invasive and radiation-free imaging modality. Renal size is influenced by some factors such as age, gender, height, weight and ethnicity [8]. Renal length is most commonly used for quantitative measure of renal size for comparison with established standards [9]. The present study was conducted in the Department of Anatomy, Kalinga Institute of Medical Sciences, Bhubaneswar, Odisha, India from October 2011 to August 2013 after the approval from the ethical committee. It was conducted in collaboration with the Department of Radiodiagnosis. The aim of this study was to evaluate the normal range of dimensions of kidney and its correlation with age, sex, height, weight and body mass index in population of eastern Odisha in different age groups by ultrasonography.

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MATERIAL AND METHODS

Real time sonography was performed on 223 subjects and all measurements were taken by the same observer. Subjects having chronic hypertensive disease, diabetes mellitus, tuberculosis, malignancy of anywhere in body, chronic kidney disease, single or multiple renal cysts, unilateral kidney, malignancy of

kidney and previous renal surgery were excluded from the study.

Initially the image was taken in supine and later in both lateral decubitus position. The measurements of kidney were taken from the freezed images in longitudinal axis and the transverse section obtained at the level of the renal hilum (Fig. 1).

Fig. 1: Renal measurements at sonography

A standardized weighing machine was used to record the weight and an infant weighing scale for infants. Measurement of the standing height was taken by the measuring scale fixed to the wall. The supine lengths were measured on an infanto-meter in children below 2 years. Height was measured and rounded to the nearest 0.5 cm. Body Mass Index (BMI) was calculated as:

$$\text{BMI (kg/m}^2\text{)} = \text{weight (kg)} / [\text{height (m)}]^2$$

Parameters for Measurement of Kidney

Length: Maximum longitudinal kidney length measured in a sagittal plane by placing the electronic calipers on the outer edges of the caudal and cranial side.

Thickness: Maximum Antero-Posterior diameters of the Transverse Section.

Width (Breadth): Maximum distance between lateral and medial border of the transverse section.

Volume: The renal volume (cm^3) was calculated from length, breadth & thickness by ellipsoid formula as $0.523 \times \text{Length (in cm)} \times \text{Width (in cm)} \times \text{Thickness (in cm)}$.

Ethics statement

The study protocol was approved by the ethics committee KIIT university, Bhubaneswar (Ref: KIIT-U/Exam/Evaluation/5752/11, Date 11/11/2011). Written informed consent was obtained from all subjects.

RESULTS

Data analysis was done by using software SPSS 13 version. Table 1 presents age and sex wise distribution of subjects at interval of 10 years. The analysis of the parameters by ten years age group was done through an ANOVA and presented in Table 2 for right kidney. The mean length of right kidney was 94.4 ± 11.8 mm, the mean breadth was 41.2 ± 8 mm, the mean thickness was 46.2 ± 9.5 mm and the mean volume was 98.3 ± 38.2 cm^3 and significant statistically ($p = 0.000$). The mean right renal length, breadth, thickness and volume increased with age upto 50 years and after that there was a decline trend. The mean volume of right kidney showed slight increase trend between 61-70 years (Table 2, Fig. 2).

Table 1: Age and sex wise distribution of subjects

Age Group (Years)	Total Number	Sex			
		Male		Female	
		Number	%	Number	%
≤10	26	15	57.7	11	42.3
11 - 20	42	24	57.1	18	42.9
21 - 30	48	18	37.5	30	62.5
31 - 40	42	21	50.0	21	50.0
41- 50	28	14	50.0	14	50.0
51 - 60	18	4	22.2	14	77.8
61 - 70	19	9	47.4	10	52.6
Total	223	105	47.1	118	52.9

Table 2: Right renal dimensions distributed by age (grouped by decade of life)

Parameters	Age Group (years)	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum	f & p Value
					Lower Bound	Upper Bound			
Length Right Kidney (mm)	≤10	26	75.208	11.679	70.491	79.925	55.3	97.7	21.270
	11 - 20	42	94.048	9.250	91.165	96.930	72.7	109.4	
	21 - 30	48	98.152	9.201	95.480	100.824	80.4	119.5	
	31 - 40	42	97.926	10.167	94.758	101.094	78.7	120.1	
	41- 50	28	99.043	8.600	95.708	102.378	84.4	122.7	0.000
	51 - 60	18	96.439	6.333	93.290	99.588	80.7	110.5	
	61 - 70	19	95.542	9.493	90.967	100.117	78.9	113.5	
	Total	223	94.413	11.801	92.855	95.970	55.3	122.7	
Breadth Right Kidney (mm)	≤10	26	30.462	5.182	28.369	32.555	21.9	43.1	14.527
	11 - 20	42	40.050	6.522	38.017	42.083	29.8	53.4	
	21 - 30	48	44.677	8.739	42.140	47.215	31.3	63.9	
	31 - 40	42	44.136	6.518	42.105	46.167	34.1	62.1	
	41- 50	28	41.882	7.071	39.140	44.624	32.1	57.6	0.000
	51 - 60	18	40.961	4.808	38.570	43.352	34.6	52.9	
	61 - 70	19	42.858	5.663	40.129	45.587	32.9	50.3	
	Total	223	41.240	7.978	40.188	42.293	21.9	63.9	

Parameters	Age Group (years)	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum	f & p Value
					Lower Bound	Upper Bound			
Thickness Right Kidney (mm)	≤10	26	35.342	6.125	32.869	37.816	25.3	47.3	9.453
	11 - 20	42	44.826	9.127	41.982	47.670	31.9	73	
	21 - 30	48	48.863	8.641	46.353	51.372	34.2	62.9	
	31 - 40	42	48.648	8.980	45.849	51.446	36.2	73.9	
	41- 50	28	48.911	8.295	45.694	52.127	30.5	67.9	0.000
	51 - 60	18	44.861	10.758	39.511	50.211	32	64.8	
	61 - 70	19	49.479	7.143	46.036	52.922	38.9	61.9	
	Total	223	46.221	9.513	44.966	47.477	25.3	73.9	
Volume Right Kidney (cm ³)	≤10	26	43.723	16.633	37.004	50.441	20.3	76.9	16.330
	11 - 20	42	92.019	34.677	81.213	102.825	37	198.2	
	21 - 30	48	112.511	35.061	102.331	122.692	57.6	193	
	31 - 40	42	111.665	32.960	101.394	121.936	62.7	192.7	
	41- 50	28	109.434	35.694	95.593	123.275	58.9	196	0.000
	51 - 60	18	97.767	28.273	83.707	111.826	63.3	171.8	
	61 - 70	19	106.032	29.761	91.687	120.376	55.5	174.4	
	Total	223	98.344	38.166	93.307	103.380	20.3	198.2	

The mean left renal length was 97.4 ± 12 mm, the mean breadth was 46.4 ± 7.6 mm, the mean thickness was 47.5 ± 8.2 mm & the mean volume was 115.8 ± 41.1 cm³ and correlated statistically significant ($p = 0.000$). The mean length, breadth & volume increased

up to 41-50 years age group and in thickness the increase was up to 51-60 years age group, after that there was a declining trend up to 70 years (Table 3, Fig. 3).

Table 3: Left renal dimensions distributed by age (grouped by decade of life)

Parameters	Age Group (years)	N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum	f & p Value
					Lower Bound	Upper Bound			
Length Left Kidney (mm)	≤10	26	76.623	9.812	72.660	80.586	56.6	95.3	26.141
	11 - 20	42	96.864	9.901	93.779	99.950	69.5	121	
	21 - 30	48	101.719	8.642	99.209	104.228	82.2	120.7	
	31 - 40	42	100.783	9.815	97.725	103.842	78.1	121.9	
	41- 50	28	103.236	10.147	99.301	107.170	87.1	136.8	0.000

	51 - 60	18	99.494	5.312	96.853	102.136	89.2	111.1	
	61 - 70	19	97.458	9.556	92.852	102.064	81.4	118.5	
	Total	223	97.350	12.087	95.755	98.945	56.6	136.8	
Breadth Left Kidney (mm)	≤10	26	35.565	6.787	32.824	38.307	25.8	49.5	15.681
	11 - 20	42	45.388	7.678	42.996	47.781	30	58.7	
	21 - 30	48	49.152	5.798	47.468	50.836	39.4	61.6	
	31 - 40	42	48.688	6.968	46.517	50.859	38.5	69.1	
	41- 50	28	48.654	5.444	46.543	50.764	35.5	60.7	0.000
	51 - 60	18	46.356	5.333	43.703	49.008	38.4	56.5	
	61 - 70	19	48.074	5.118	45.607	50.540	37.6	55.7	
	Total	223	46.391	7.584	45.391	47.392	25.8	69.1	
Thickness Left Kidney (mm)	≤10	26	36.027	6.660	33.337	38.717	24.2	48.4	15.296
	11 - 20	42	46.348	7.686	43.953	48.743	34.9	66.9	
	21 - 30	48	51.260	7.304	49.140	53.381	38.2	73	
	31 - 40	42	49.593	6.154	47.675	51.511	33.1	67	
	41- 50	28	48.868	6.043	46.524	51.211	39.5	61	0.000
	51 - 60	18	49.722	8.171	45.659	53.785	40.8	64.4	
	61 - 70	19	47.837	6.838	44.541	51.133	37.4	62	
	Total	223	47.529	8.230	46.443	48.615	24.2	73	
Volume Left Kidney (cm³)	≤10	26	53.377	22.242	44.393	62.360	20.9	97.1	19.845
	11 - 20	42	109.196	38.288	97.265	121.127	48.2	205.8	
	21 - 30	48	134.885	35.387	124.610	145.161	77.9	232.4	
	31 - 40	42	129.747	34.825	118.895	140.599	54	219	
	41- 50	28	128.268	28.100	117.372	139.164	87.8	211	0.000
	51 - 60	18	115.578	39.414	95.978	135.178	11.6	182.3	
	61 - 70	19	118.968	26.991	105.959	131.978	81.2	165.8	
	Total	223	115.830	41.113	110.405	121.256	11.6	232.4

Fig. 2: Parameters of right kidney by age
A-Length of kidney B- Breadth of kidney C-Thickness of kidney D- Volume of kidney

Fig. 3: Parameters of left kidney by age

The mean values of parameters of right and left kidneys were analysed respectively by sex along with significant values of 't' test (Table 4 & 5). It was found

that all the parameters of male kidney were larger than female kidney on both sides (Fig. 4 & 5) and significant statistically except the length.

Table 4: Comparison of parameters of right kidney by sex

Group Statistics	Sex	N	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval for Mean		t Value	p Value
						Lower Bound	Upper Bound		
Length Right Kidney (mm)	Male	105	94.866	13.777	1.345	92.230	97.501	0.530	0.597
	Female	118	94.009	9.757	0.898	92.249	95.770		
Breadth Right Kidney (mm)	Male	105	42.624	8.821	0.861	40.937	44.311	2.437	0.016
	Female	118	40.009	6.953	0.640	38.755	41.264		
Thickness Right Kidney (mm)	Male	105	47.540	9.538	0.931	45.716	49.364	1.964	0.051
	Female	118	45.047	9.375	0.863	43.356	46.739		
Volume Right Kidney (cm ³)	Male	105	106.66	43.842	4.279	98.278	115.050	3.069	0.002
	Female	118	90.940	30.626	2.819	85.414	96.466		

Table 5: Comparison of parameters of left kidney by sex

Sex	Sex	N	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval for Mean		t Value	p Value
						Lower Bound	Upper Bound		
Length Left Kidney (mm)	Male	105	98.181	14.052	1.371	95.493	100.869	0.950	0.343
	Female	118	96.611	10.026	0.923	94.802	98.420		
Breadth Left Kidney (mm)	Male	105	47.437	8.699	0.849	45.773	49.101	1.920	0.056
	Female	118	45.461	6.325	0.582	44.320	46.602		
Thickness Left Kidney (mm)	Male	105	49.146	8.762	0.855	47.470	50.822	2.784	0.006
	Female	118	46.090	7.474	0.688	44.741	47.438		
Volume Left Kidney (cm ³)	Male	105	124.534	46.865	4.574	115.57	133.498	2.980	0.003
	Female	118	108.086	33.562	3.090	102.03	114.142

Fig. 4: Parameters of right kidney by sex

Fig. 5: Parameters of left kidney by sex

The mean parameters of kidney by different weight groups for right and left kidneys respectively were analysed which revealed that as the weight

increases the parameters of kidney also increases and significant statistically ($p = 0.000$) (Table 6 & 7, Fig. 6 & 7).

Table 6: Relationship between right renal dimensions and individual's weight (kg)

Parameters	Weight Groups	Mean	Std. Deviation	95% Confidence Interval for Mean		f value	p value
				Lower Bound	Upper Bound		
Length Right Kidney (mm)	≤30	75.663	11.186	71.486	79.840	47.462	0.000
	31 - 40	89.944	7.878	86.828	93.061		
	41 - 50	95.732	5.683	94.063	97.401		
	51 - 60	96.401	8.647	94.308	98.495		
	61 - 70	103.021	7.304	100.472	105.569		
	>70	105.776	8.909	101.196	110.357		
	Total	94.413	11.801	92.855	95.970		
Breadth Right Kidney (mm)	≤30	30.710	4.866	28.893	32.527	33.340	0.000
	31 - 40	38.522	5.640	36.291	40.753		
	41 - 50	40.462	5.407	38.874	42.049		
	51 - 60	42.250	6.192	40.751	43.749		
	61 - 70	47.906	7.552	45.271	50.541		
	>70	48.924	6.524	45.569	52.278		
	Total	41.240	7.978	40.188	42.293		
Thickness Right	≤30	36.193	6.235	33.865	38.522	16.646	0.000
	31 - 40	43.974	8.549	40.592	47.356		

Parameters	Weight Groups	Mean	Std. Deviation	95% Confidence Interval for Mean		f value	p value
				Lower Bound	Upper Bound		
Kidney (mm)	41 - 50	43.660	7.540	41.446	45.874		
	51 - 60	49.518	7.946	47.594	51.441		
	61 - 70	52.085	10.927	48.273	55.898		
	>70	49.653	6.654	46.232	53.074		
	Total	46.221	9.513	44.966	47.477		
Volume Right Kidney (cm³)	≤30	45.426	16.673	39.201	51.652	44.192	0.000
	31 - 40	81.041	22.883	71.988	90.093		
	41 - 50	90.480	22.108	83.989	96.971		
	51 - 60	107.858	29.862	100.629	115.086		
	61 - 70	132.432	33.838	120.625	144.239		
	>70	134.718	34.035	117.219	152.217		
	Total	98.344	38.166	93.307	103.380		

Table 7: Relationship between left renal dimensions and individual's weight (kg)

Parameters	Weight Groups	Mean	Std. Deviation	95% Confidence Interval for Mean		f value	p value
				Lower Bound	Upper Bound		
Length Left Kidney (mm)	≤30	77.883	10.458	73.978	81.788	42.406	0.000
	31 - 40	95.552	8.187	92.313	98.790		
	41 - 50	97.557	8.448	95.077	100.038		
	51 - 60	99.919	8.358	97.896	101.942		
	61 - 70	104.794	7.791	102.076	107.513		
	>70	108.824	9.759	103.806	113.841		
	Total	97.350	12.087	95.755	98.945		
Breadth Left Kidney (mm)	≤30	36.583	7.089	33.936	39.230	25.788	0.000
	31 - 40	43.496	7.332	40.596	46.397		
	41 - 50	45.906	4.528	44.577	47.236		
	51 - 60	48.400	6.203	46.898	49.902		
	61 - 70	50.765	6.347	48.550	52.979		
	>70	52.859	4.351	50.622	55.096		

Parameters	Weight Groups	Mean	Std. Deviation	95% Confidence Interval for Mean		f value	p value
				Lower Bound	Upper Bound		
Thickness Left Kidney (mm)	Total	46.391	7.584	45.391	47.392	22.226	0.000
	≤30	36.603	6.444	34.197	39.009		
	31 - 40	45.922	6.915	43.187	48.658		
	41 - 50	47.100	6.608	45.160	49.040		
	51 - 60	50.087	6.516	48.509	51.664		
	61 - 70	52.574	7.525	49.948	55.199		
	>70	50.224	6.961	46.644	53.803		
Volume Left Kidney (cm ³)	Total	47.529	8.230	46.443	48.615	37.387	0.000
	≤30	56.820	23.353	48.099	65.540		
	31 - 40	101.623	29.259	90.049	113.198		
	41 - 50	111.474	27.596	103.372	119.576		
	51 - 60	125.658	34.518	117.303	134.013		
	61 - 70	147.419	32.892	135.942	158.895		
	>70	152.088	28.449	137.461	166.715		
	Total	115.830	41.113	110.405	121.256

Fig. 6: Parameters of right kidney by weight

A-Length of kidney B- Breadth of kidney C-Thickness of kidney D- Volume of kidney

Fig. 7: Parameters of left kidney by weight

The mean of parameters of right and left kidney along with ANOVA results according to height was analysed (Table 8 & 9, Fig. 8 & 9) and it was seen that

there was an increasing trend of the magnitude of parameters with height, which was statistically significant ($p = 0.000$).

Table 8. Relationship between right renal dimensions and individual's height (cm)

Parameters	Height Groups	Mean	Std. Deviation	95% Confidence Interval for Mean		f & p Value
				Lower Bound	Upper Bound	
Length Right Kidney (mm)	≤130	75.104	11.558	70.333	79.875	48.671
	131 - 150	93.917	8.609	91.521	96.314	
	151 - 170	96.743	9.195	95.108	98.377	
	>170	105.076	7.479	101.672	108.481	0.000
	Total	94.432	11.824	92.868	95.996	
Breadth Right Kidney (mm)	≤130	30.620	5.388	28.396	32.844	37.723
	131 - 150	38.390	5.897	36.749	40.032	
	151 - 170	43.476	6.777	42.271	44.680	
	>170	47.990	7.626	44.519	51.462	0.000
	Total	41.264	7.988	40.207	42.320	
Thickness Right Kidney (mm)	≤130	35.408	6.113	32.885	37.931	17.003
	131 - 150	45.398	8.242	43.104	47.693	
	151 - 170	48.002	9.251	46.357	49.646	
	>170	50.867	8.280	47.098	54.636	0.000
	Total	46.245	9.528	44.984	47.505	
Volume Right Kidney (cm³)	≤130	44.148	17.254	37.025	51.270	42.534
	131 - 150	88.606	25.839	81.412	95.799	
	151 - 170	107.030	33.181	101.132	112.928	
	>170	137.010	36.658	120.323	153.696	0.000
	Total	98.469	38.206	93.416	103.523	

Table 9. Relationship between left renal dimensions and individual's height (cm)

Parameters	Height Groups	Mean	Std. Deviation	95% Confidence Interval for Mean		f & p Value
				Lower Bound	Upper Bound	
Length Left Kidney (mm)	≤130	76.120	9.718	72.109	80.131	55.924
	131 - 150	96.729	8.665	94.316	99.141	
	151 - 170	100.406	8.957	98.813	101.998	
	>170	106.233	10.863	101.289	111.178	0.000

Parameters	Height Groups	Mean	Std. Deviation	95% Confidence Interval for Mean		f & p Value
				Lower Bound	Upper Bound	
	Total	97.361	12.113	95.759	98.963	
Breadth Left Kidney (mm)	≤130	35.612	6.338	32.996	38.228	29.571
	131 - 150	45.656	5.952	43.999	47.313	
	151 - 170	48.360	6.450	47.213	49.506	
	>170	49.871	7.499	46.458	53.285	
	Total	46.434	7.574	45.432	47.436	0.000
Thickness Left Kidney (mm)	≤130	35.924	6.759	33.134	38.714	29.889
	131 - 150	46.227	6.687	44.365	48.089	
	151 - 170	50.048	7.080	48.790	51.307	
	>170	50.000	7.354	46.652	53.348	
	Total	47.558	8.237	46.469	48.648	0.000
Volume Left Kidney (cm ³)	≤130	52.916	21.566	44.014	61.818	38.681
	131 - 150	109.231	30.589	100.715	117.748	
	151 - 170	127.686	35.739	121.333	134.039	
	>170	138.910	37.358	121.904	155.915	
	Total	116.005	41.123	110.566	121.444	0.000

Fig. 8: Parameters of right kidney by height
A-Length of kidney B- Breadth of kidney C-Thickness of kidney D- Volume of kidney

Fig. 9: Parameters of left kidney by height
A-Length of kidney B- Breadth of kidney C-Thickness of kidney D- Volume of kidney

The ANOVA results of the variation of parameters of kidney with the BMI, are represented in Table 10 and Fig. 10 for right kidney parameters and in Table 11 and Fig. 11 for left kidney parameters. The mean

length, thickness, breadth and volume showed strong correlation with all the BMI groups and statistically significant ($p = 0.000$).

Table 10. Relationship between right renal dimensions and individual's BMI (kg/m²)

Parameters	BMI Groups	Mean	Std. Deviation	95% Confidence Interval for Mean		f value	p value
				Lower Bound	Upper Bound		
Length Right Kidney (mm)	≤ 15	77.921	10.144	73.988	81.855	18.280	0.000
	>15 & ≤ 17	88.927	11.354	84.341	93.513		
	>17 & ≤ 19	95.104	10.223	90.788	99.421		
	>19 & ≤ 21	95.474	9.648	92.302	98.645		
	>21 & ≤ 23	99.191	8.390	96.216	102.166		
	>23 & ≤ 25	97.871	9.327	94.616	101.125		
	>25 & ≤ 27	100.121	7.629	96.899	103.342		
	>27	102.863	8.454	98.358	107.367		
Breadth Right Kidney (mm)	≤ 15	32.118	4.518	30.366	33.870	12.319	0.000
	>15 & ≤ 17	37.831	6.846	35.065	40.596		
	>17 & ≤ 19	40.942	5.709	38.531	43.352		
	>19 & ≤ 21	40.603	7.227	38.227	42.978		
	>21 & ≤ 23	43.730	8.186	40.828	46.633		
	>23 & ≤ 25	44.812	5.537	42.880	46.744		
	>25 & ≤ 27	44.996	8.640	41.348	48.644		
	>27	46.350	7.329	42.444	50.256		
Thickness Right Kidney (mm)	≤ 15	39.854	7.988	36.756	42.951	6.921	0.000
	>15 & ≤ 17	41.231	7.856	38.058	44.404		
	>17 & ≤ 19	43.292	8.589	39.665	46.918		
	>19 & ≤ 21	46.184	9.350	43.111	49.258		
	>21 & ≤ 23	48.152	9.814	44.672	51.631		
	>23 & ≤ 25	52.353	8.980	49.220	55.486		
	>25 & ≤ 27	48.404	8.477	44.825	51.984		
	>27	49.669	7.317	45.770	53.568		
Volume Right Kidney (cm³)	≤ 15	53.443	19.847	45.747	61.138	15.825	0.000
	>15 & ≤ 17	75.332	28.459	63.837	86.826		
	>17 & ≤ 19	91.492	27.131	80.035	102.948		
	>19 & ≤ 21	100.912	38.346	88.308	113.516		
	>21 & ≤ 23	109.724	32.118	98.336	121.113		
	>23 & ≤ 25	122.168	32.250	110.916	133.421		
	>25 & ≤ 27	112.262	35.500	97.272	127.253		
	>27	123.518	31.499	106.733	140.302		

Table 11. Relationship between left renal dimensions and individual's BMI (kg/m²)

Parameters	BMI Groups	Mean	Std. Deviation	95% Confidence Interval for Mean		f value	p value
				Lower Bound	Upper Bound		
Length Left Kidney (mm)	≤ 15	82.029	12.214	77.293	86.765	14.890	0.000
	>15 & ≤ 17	90.065	11.306	85.499	94.632		
	>17 & ≤ 19	99.613	8.730	95.926	103.299		
	>19 & ≤ 21	99.482	11.181	95.807	103.157		
	>21 & ≤ 23	100.303	10.736	96.496	104.110		
	>23 & ≤ 25	102.409	7.637	99.744	105.074		
	>25 & ≤ 27	101.858	6.089	99.287	104.429		
	>27	103.944	10.882	98.145	109.742		
Breadth Left Kidney (mm)	≤ 15	38.086	6.748	35.469	40.702	10.919	0.000
	>15 & ≤ 17	42.200	7.994	38.971	45.429		
	>17 & ≤ 19	46.521	7.736	43.254	49.787		
	>19 & ≤ 21	47.226	7.014	44.921	49.532		
	>21 & ≤ 23	48.818	6.354	46.565	51.071		
	>23 & ≤ 25	48.629	5.111	46.846	50.413		
	>25 & ≤ 27	50.346	5.136	48.177	52.514		
	>27	49.869	6.510	46.400	53.338		
Thickness Left Kidney (mm)	≤ 15	39.846	6.618	37.280	42.413	7.408	0.000
	>15 & ≤ 17	43.750	8.163	40.453	47.047		
	>17 & ≤ 19	49.392	7.972	46.026	52.758		
	>19 & ≤ 21	48.274	9.604	45.117	51.430		
	>21 & ≤ 23	47.488	5.885	45.401	49.575		
	>23 & ≤ 25	51.044	6.348	48.829	53.259		
	>25 & ≤ 27	50.704	7.366	47.594	53.815		
	>27	50.400	6.864	46.743	54.057		
Volume Left Kidney (cm³)	≤ 15	67.060	24.616	57.515	76.605	13.675	0.000
	>15 & ≤ 17	90.221	32.452	77.113	103.329		
	>17 & ≤ 19	122.376	39.343	105.763	138.989		
	>19 & ≤ 21	121.896	43.036	107.750	136.041		
	>21 & ≤ 23	122.888	34.926	110.504	135.272		
	>23 & ≤ 25	130.973	31.497	119.983	141.963		
	>25 & ≤ 27	137.967	34.519	123.390	152.543		
	>27	138.633	30.155	122.564	154.702

Fig. 10: Parameters of right kidney vs BMI
A-Length of kidney B- Breadth of kidney C-Thickness of kidney D- Volume of kidney

Fig. 11: Parameters of left kidney vs BMI
A-Length of kidney B- Breadth of kidney C-Thickness of kidney D- Volume of kidney

DISCUSSION

Ultrasonographic renal size is one of the easily reproducible parameter and provides rough indication of the renal function. Therapeutic decisions are frequently based on the size of the kidney. A small kidney size is an indication of irreversible chronic renal failure. Hence, it is important that the method of measuring the organ should accurate and precise. One could start with an ultrasonographic measurement of renal length and reserve MR imaging as a second-level method in case of uncertainty. When the renal length is 10 cm or longer, one would be 'safe' to start certain treatment or can perform certain procedure. Since the estimation of renal volume requires measurement of three dimensions of the kidney, the error increases in geometric proportion while calculating the volume. Hence it is simpler to use renal length as a yardstick for comparing renal growth with body growth [10,11].

Investigators studying intra- and inter-observer variations in renal length and volume measurements with USG have found comparable or slightly better repeatability. For example, Emamian et al. [12] found a relative SD of the difference of 4%–5% for renal length and of 14%–17% for renal volume in adults.

In the present study in 63.68%, the left kidney length was larger than right side. The kidney volume in the present study was $98.3 \pm 38.1 \text{ cm}^3$ on right side and $115.8 \pm 41.1 \text{ cm}^3$ on left side. This study correlate with the study of Raza et al. (2011) [11] and Arooj et al. (2011) [13]. The kidney volumes in the study by Emamian et al. (1993) [12] were larger than this study, may be due to larger habitus of the western population. In the present study, the kidney volume was found to be larger on left side in 81.17%, right side in 18.39% and equal in 0.45%. Study by Dinkel et al. (1985) found renal volume to be greater on the left in 51.7%, on the right in 29.5% and of equal size in 18.8% [14]. In the present study, the left kidney was significantly larger than the right (Table 12), which was similar to the results of many studies like Oyuela Carrasco et al. (2009) [15], Fernandes et al. (2002) [16], Dinkel et al. (1985) [14], Gavela et al. (2006) [17]. This difference could be explained by the fact that the liver being bigger than the spleen, for which the right kidney has less space to grow. Another possible explanation is related to the shorter length of the left renal artery, which increases blood flow to the left kidney which in turn increases the volume and size of the left kidney [12].

Table – 12 Correlation of parameters of right and left kidney in different studies

	Parameters	Present Study (2017)	Mujahid et al. (2011) [11]	Arooj et al. (2011) [13]	Buchholz et al. (2000) [2]
Right Kidney	Length (mm)	94.4±11.8	101.6±8.9	97±7.9	104±9
	Breadth (mm)	41.2±7.9	42.7±7.1	38±5.2	42±7
	Thickness (mm)	46.2±9.5		38±5.7	
	Volume (cm ³)	98.3±38.1	99.8±37.2	71.5±18.8	
Left Kidney	Length (mm)	97.3±12.0	102.7±9.2	99±9.6	105±9
	Breadth (mm)	46.3±7.6	47.6±7	44±5.9	48±7
	Thickness (mm)	47.5±82.2		43±7.9	
	Volume (cm ³)	115.8±41.1	124.4±41.3	93.6±27.6	

In the present study, there was sharp increase in measurements of parameters till the age of 20 years and slight increase up to 30 years and thereafter, it remained stable beyond 30 years up to 50 years. The above analysis leads us to formulate the hypothesis that the parameters of kidney might have attained its full growth by the age of 11-20 years and corroborates with the findings of Buchholz et al. (2000) [2]. Han and Babcock modelled renal growth according to two separate linear models—one from birth to age 1 year and another from age 1–18 years. Their model estimates growth to be 0.15 cm per month in the first year and 0.27 cm per year thereafter [18]. A decline in trend in all the measurements of parameters beyond 50 years was observed in the present study similar to study by Reshaid and Fattah (2014) [19]. However, the mean volume on both sides had a slight increasing trend in the age group 61-70 years, which may be due to relaxation of the abdominal wall with advancing age, so that the kidneys are squeezed less in older persons.

In the present study, it was found that all the parameters of kidney in male were larger than female on both sides and differed statistically significantly. This corroborates with the result by Raza et al. (2011) [11], Emamian et al. (1993) [12], Arooj et al. (2011) [13], Hekmatnia and Yaraghi (2004) [7], Oyuela Carrasco et al. (2009) [15], Fernandes et al. (2002) [16], Gao et al. (2011) [20], Mustafa and Ahmed (2017) [21]. In this present study, all the parameters of kidney correlates well with height, weight and BMI and are statistically significant ($p=0.000$). However, best correlation was found with height and weight. Raza et

al. (2011) also showed a significant positive relationship of the subject's height and weight with renal volume and renal length in both genders [11]. This finding is very much in line with the studies of many workers such as Emamian et al. (1993) [12], Gavela et al. (2006) [17], Buchholz et al. (2000) [2], Fernandes et al. (2002) [16] and Oyuela Carrasco et al. (2009) [15]. However Reshaid and Fattah (2014) observed that renal length of the two sides correlate in a significantly positive manner with weight and BMI, and weakly with height [19], in contrast to other studies in adults where the strength of this association has been significantly greater with height [12,15,20].

The data in the present study show that the mean values obtained for the dimensions of both kidneys was similar to the study done by Raza et al. (2011) [11], Buchholz et al. (2000) [2] and Zeb et al. (2012) [22] as the population under these studies, belonged to South East Asia. The mean values were below those found in European studies. It is known that the Westerners are taller and bigger compared to Asians [13]. The organs of Asians are generally accepted to be smaller than that of Westerners [23].

CONCLUSION

In this study in all age groups the ultrasonographic mean dimensions of right kidney were length 94.4 ± 11.8 mm, breadth 41.2 ± 7.9 mm, thickness 46.2 ± 9.5 mm and volume 98.3 ± 38.2 cm³ and the mean measurements of left kidney were length 97.4 ± 12.1 mm, breadth 46.4 ± 7.6 mm, thickness 47.5 ± 8.2 mm and volume 115.8 ± 41.1 cm³. The parameters were

smaller than previously reported, is probably a reflection of the relatively small body size of South East Asians than western population. Left kidney was larger than Right kidney. Kidneys were significantly larger in male than female. All the measurements of parameters of both right and left kidney correlated significantly with age, height, weight and BMI. Maximum growth period noted in this study was up to 20 years of age. Thereafter, there was minimal growth up to 50 years. Slight decline in trend in all the measurements of parameters beyond 50 years was observed.

Conflict of Interest: None

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