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A Study of Different Morphological Parameters of Kidneys in the Indian Population

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Abstract: ***The kidneys are dynamic organs. Their morphological parameters, such as length, breadth, thickness, volume and weight vary with age, sex and laterality. The parameters also vary noticeably among different populations across the world. As renal dimensions are important in determining the treatment modalities in different renal diseases as well as in assessment of suitability in renal transplant, it is important to study the variations in the morphometry of the kidneys. In our present study, we measured the pole - to - pole length, breadth, anteroposterior thickness, volume and weight of 240 kidneys in 120 cadavers that were brought to the morgue of a government medical college and hospital in West Bengal, India. We then tabulated the data according to the age and sex of the subjects to look for variations in the parameters with respect to age, sex and laterality. We found that all the morphological parameters of the kidneys increased in age up to 40 years of age. Thereafter, the kidneys showed signs of shrinkage and all the parameters decreased progressively. The male kidneys were found to be larger than the female kidneys. The left kidneys were found to be longer than the right kidneys. Our findings are at par with similar studies done in India and adjoining regions by other authors. However, the figures are much lesser than that found in the Western population and that quoted by standard Anatomy textbooks. As morphological parameters of the kidney are clinically important, it is essential for standardisation of renal dimensions among the Indian population.***

Keywords: kidneys, renal length, renal breadth, renal thickness, renal volume, renal weight

1. Introduction

The kidneys are essential organs of the body which serve important excretory and endocrine functions. Estimation of the size of kidneys is crucial as a part of clinical assessment of the organ. The size of a kidney can be measured by its morphological parameters such as its length, breadth, thickness, weight and volume. [1]

According to standard textbooks of Human Anatomy, each kidney is typically 11 - 12 cm in length, 6 cm in breadth and 3 cm in anteroposterior thickness. The left kidney can be upto 1.5 cm longer than the right kidney. The kidneys in females are usually smaller when compared to males. The average weight of a kidney is 150 gm in males and 135 gm in females. [2, 3]

The kidneys are dynamic organs. Marked structural and functional changes are observed in the organ with age. The kidneys are thought to grow in its length, breadth, thickness etc. until middle age, after which marked degenerative changes are noticed. Such changes are considered non - pathological. It is thought that degeneration of the cortex of the kidneys in old age is responsible for the overall shrinkage of the kidneys. [4]

Kidney length and volume measurements are important for the assessment of prognosis in patients with chronic systemic diseases such as diabetes or renal artery stenosis. They are also important for renal transplant candidates as well as in kidney donors, where the suitability of the donor kidney is judged. [5, 6] Sometimes, renal dimensions dictate further course of action in different renal diseases. For example, if the kidney length is less than 8 cm in a patient with renal artery stenosis, surgical interventions are usually contraindicated. [7]

The measurement of the different morphological parameters of the kidney can be done by various modalities, such as direct measurement of the viscera during dissection of fresh cadavers or by radiological techniques such as intravenous pyelography, USG, CT and MRI in live subjects. Reports show that the radiological modalities tend to underestimate the renal size by 17 - 20%. [7] In the present study, we aimed to measure the different morphological parameters of kidneys in the fresh cadavers brought to the mortuary of a government medical college and hospital in West Bengal for autopsy.

2. Materials and Methods

We conducted a descriptive study of cross sectional design over a period of one year in a government medical college and hospital of West Bengal with the relevant permission from the Institutional Ethics Committee as well as the departments of Forensic Medicine and Anatomy. The kidneys of both sides were measured in 120 cadavers across both sexes and irrespective of age. The remains of patients who died due to renal causes or severe abdominal trauma were excluded. Similarly, cadavers of subjects with known history of chronic diseases such as diabetes and hypertension were also not considered for the study. Cadavers were also not included if they were unclaimed, mutilated or if their family members were unwilling to consent to the study.

We measured the pole - to - pole length, breadth, anteroposterior thickness, weight and volume of 240 kidneys belonging to the 120 subjects of our study. The age of the subjects were collected from the autopsy records. For all linear measurements, such as length, breadth and thickness, digital callipers were used. The weight was measured using a digital weighing machine. The volume of the kidneys were calculated using the ellipsoid method [8]. The formula we used is as follows:

Volume = (Length x Breadth x Thickness) x □/6

We then divided our subjects into different groups based on their sex and their age. Thereafter, we observed the different morphological parameters of their kidneys with respect to age and laterality.

3. Results

Of the 120 subjects of our study, 46 (38.33%) were female and 74 (61.67%) were male.28 subjects (23.33%) were aged between 11 and 20 years, 25 (20.83%) between 21 and 30 years, 19 (15.83%) between 31 and 40, 9 (7.5%) between 41 and 50, 15 (12.5%) between 51 and 60, 14 (11.67%) between 61 and 70 and 10 (8.34%) were above 70 years of age. We divided them into seven age groups accordingly.

The average length of the left kidney among our study sample was 7.92 ± 0.66 cm and that of the right kidney was 7.52 ± 0.64 cm. So, left kidneys were found to be longer than right kidneys on average. The mean length of the kidneys of both sides was found to increase with age across the first three age groups i. e.11 - 20 years, 21 - 30 years and 31 - 40 years. Thereafter, the mean length was found to gradually decline across the remaining four age groups. [Table 1] Also, the average size of the kidneys were found to be smaller in females (7.34 ± 0.50 cm on the left, 6.97 ± 0.50 cm on the right) when compared to the male subjects (8.28 ± 0.47 cm on the left and 7.85 ± 0.45 cm on the right). [Table 2]

Table 1: Distribution of length of kidney according to age group and laterality

Age (in yrs)	n	Mean breadth (cm) [Left]	SD	Mean breadth (cm) [Right]	SD
11- 20	28	7.34	± 0.56	6.99	± 0.52
21 - 30	25	8.29	± 0.56	7.92	± 0.55
31 - 40	19	8.43	± 0.50	7.96	± 0.49
41 - 50	9	8.13	± 0.44	7.73	± 0.41
51 - 60	15	7.99	± 0.44	7.59	± 0.45
61 - 70	14	7.62	± 0.53	7.22	± 0.54
≥ 70	10	7.48	± 0.55	7.04	± 0.56
Total	120	7.92	± 0.66	7.52	± 0.64

Table 2: Distribution of mean length of kidney according to sex and laterality

Sex	n	Mean breadth (cm) [Left]	SD	Mean breadth (cm) [Right]	SD
Female	46	7.34	± 0.50	6.97	± 0.50
Male	74	8.26	± 0.47	7.85	± 0.45
Total	120	7.92	± 0.66	7.52	± 0.64

The mean breadth of the kidneys were found to be ascending across the first three age groups of our study i. e.4.20 ± 0.41 cm, 4.27 ± 0.47 cm, and 4.39 ± 0.39 cm in age groups 11 - 20 years, 21 - 30 years and 31 - 40 years respectively. Thereafter, the mean breadth steadily declined in the older age groups. [Table 3] The average breadth of kidneys in females was found to be lower than in males. In addition, the average breadth of left kidneys (4.19 ± 0.45 cm) was smaller than that of right kidneys (4.27 ± 0.41 cm). [Table 4]

Table 3: Distribution of breadth of kidney according to age and laterality

Age (in yrs)	n	Mean breadth (cm) [Left]	SD	Mean breadth (cm) [Right]	SD
11- 20	28	4.2	± 0.41	4.29	± 0.37
21 - 30	25	4.27	± 0.47	4.33	± 0.46
31 - 40	19	4.39	± 0.39	4.46	± 0.38
41 - 50	9	4.13	± 0.47	4.25	± 0.39
51 - 60	15	4.07	± 0.36	4.17	± 0.30
61 - 70	14	3.83	± 0.35	3.95	± 0.29
≥ 70	10	3.71	± 0.37	3.79	± 0.36
Total	120	4.19	± 0.45	4.27	± 0.41

Table 4: Distribution of mean breadth of kidney according to sex and laterality

Sex	n	Mean breadth (cm) [Left]	SD	Mean breadth (cm) [Right]	SD
Female	46	3.67	± 0.27	3.8	± 0.28
Male	74	4.4	± 0.26	4.46	± 0.25
Total	120	4.19	± 0.45	4.27	± 0.41

Just like length and breadth, the mean thickness of the kidneys was found to increase progressively across the first three age groups up to 40 years of age. Subsequently, it was found to decrease gradually along the last four groups. [Table 5]

Table 5: Distribution of mean thickness of kidney across age and laterality

Age (in yrs)	n	Mean thickness (cm) [Left]	SD	Mean thickness (cm) [Right]	SD
11-20	28	2.05	± 0.23	1.97	± 0.24
21 - 30	25	2.41	± 0.22	2.34	± 0.25
31 - 40	19	2.55	± 0.30	2.46	± 0.31
41 - 50	9	2.15	± 0.31	2.07	± 0.32
51 - 60	15	1.84	± 0.17	1.77	± 0.19
61 - 70	14	1.65	± 0.15	1.58	± 0.17
>/= 70	10	1.56	± 0.12	1.5	± 0.13
Total	120	2.1	± 0.39	2.03	± 0.40

The thickness of male kidneys was found to be 2.23 ± 0.37 cm on the left and 2.17 ± 0.39 cm on the right. In contrast, the female kidneys were 1.88 ± 0.31 cm thick on the left and 1.79 ± 0.32 cm on the right. Overall, the left kidneys were thicker than the right kidneys (2.10 ± 0.39 cm on the left vs.2.03 ± 0.40 cm on the right). [Table 6]

Table 6: Distribution of mean thickness of kidneys according to sex and laterality

Sex	n	Mean thickness (cm) [Left]	SD	Mean thickness (cm) [Right]	SD
Female	46	1.88	± 0.31	1.79	± 0.32
Male	74	2.23	± 0.37	2.17	± 0.39
Total	120	2.1	± 0.39	2.03	± 0.40

Since the volume was calculated based on a formula using length, breadth and thickness, the volume also followed the same pattern of variation across the different age groups. The volume of kidneys increased gradually between 11 and 40 years of age and then started declining as the age progressed. [Table 7]

Table 7: Distribution of volume of kidneys according to age and laterality

Age (in yrs)	n	Mean volume (cc) [Left]	SD	Mean volume (cc) [Right]	SD
11-20	28	33.72	± 8.29	31.54	± 7.74
21 - 30	25	44.53	± 10.92	41.99	± 10.80
31 - 40	19	50.35	± 12.14	46.69	± 11.36
41 - 50	9	38.58	± 10.57	36.33	± 9.69
51 - 60	15	31.91	± 7.13	29.8	± 6.67
61 - 70	14	25.72	± 6.17	24.1	± 5.93
≥ 70	10	24.37	± 5.35	21.91	± 5.16
Total	120	36.96	± 12.34	34.59	± 11.86

Volume of the kidneys were found to be lesser in females than in males. Also, the mean volume of the right kidneys was found to be smaller than the mean volume of the left kidneys. [Table 8]

Table 8: Distribution of volume of kidneys according to sex and laterality

Sex	n	Mean volume (cc) [Left]	SD	Mean volume (cc) [Right]	SD
Female	46	27.01	± 7.48	25.19	± 7.26
Male	74	43.14	± 11.08	40.43	± 10.33
Total	120	36.96	± 12.34	34.59	± 11.86

Weight of the kidneys similarly increased across age groups from 11 to 40 years but was found to decrease thereafter. [Table 9] The female subjects had lighter kidneys compared to their male counterparts. Left kidneys were found to be heavier than right kidneys. [Table 10]

Table 9: Distribution of weight of kidneys according to age and laterality

Age (in yrs)	n	Mean weight (gm) [Left]	SD	Mean weight (gm) [Right]	SD
11-20	28	87.27	± 5.39	81.59	± 4.82
21 - 30	25	95.94	± 9.26	88.91	± 6.76
31 - 40	19	96.75	± 7.62	90.45	± 6.59
41 - 50	9	92.84	± 5.07	86.25	± 4.66
51 - 60	15	90.02	± 4.71	84.29	± 4.22
61 - 70	14	88.29	± 5.00	82.14	± 4.04
≥ 70	10	86.01	± 5.16	80.14	± 4.01
Total	120	91.49	± 7.49	85.56	± 6.26

Table 10: Distribution of weight of kidneys according to sex and laterality

Sex	n	Mean weight (gm) [Left]	SD	Mean weight (gm) [Right]	SD
Female	46	82.25	± 4.06	80.44	± 4.05
Male	74	95.36	± 6.44	88.74	± 5.19
Total	120	91.49	± 7.49	85.56	± 6.26

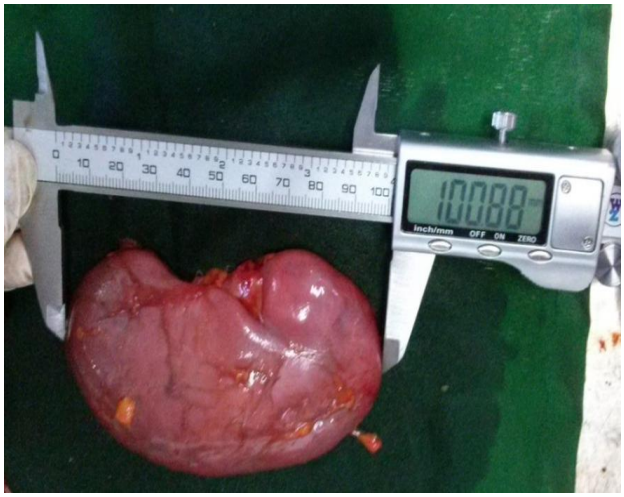

Figure 1: Measurement of pole - to - pole length of kidney

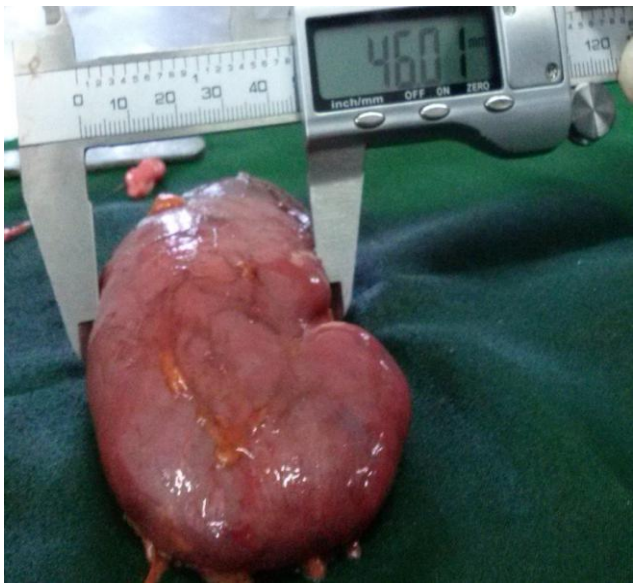

Figure 2: Measurement of breadth of kidney

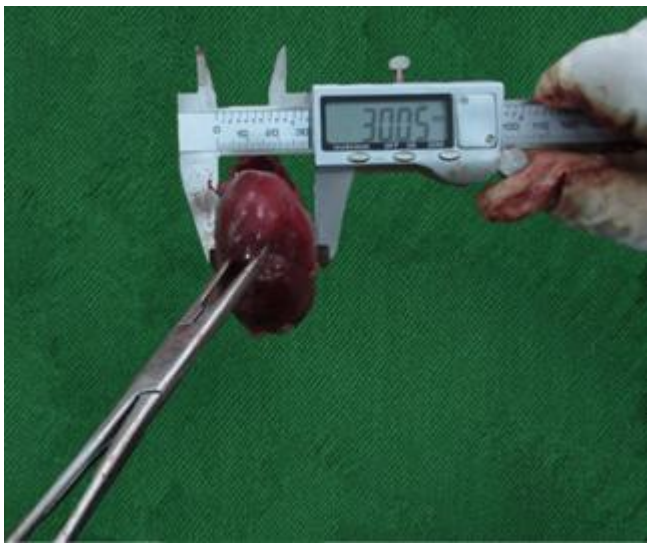

Figure 3: Measurement of anteroposterior thickness of kidney

4. Discussion

A review of the existing literature over time shows notable differences in the renal morphological parameters in

different age groups and sexes as well as among different study populations. All the parameters of the kidney have been found to be higher among the Caucasians than among the Asians, particularly the South Asian population.

We found that the mean length, breadth and thickness of the kidneys continue to increase with age due to growth of the organ. However, the morphological parameters peak by the age of forty years. Thereafter, the kidneys start shrinking due to non - pathological senile atrophy of the renal cortex and the dimensions of the kidney keep steadily decreasing as the age of a person advances. This would also explain why the volume and the weight of the kidney would also show a similar pattern of variation. While some authors like Anderson and Weinstein [9] say that the cortical shrinkage is due to loss of glomeruli, others such as Martin and Sheaff [10] suggest that tubulo - interstitial changes also play a role.

Kidneys in males are larger and heavier than that in females. This could be explained by the fact that males have a larger body surface area than females in general. So it is fair to assume that the internal viscera in males would also be larger than in females. This assumption also explains why we have found the dimensions much smaller than the studies performed in the Western population, such as by Glodny et al [11], who typically have a larger stature, body weight and body surface area than the South Asians.

However, our findings are along the same lines as findings of the studies performed by various authors among the Indian population by authors like Satheesh et al [12] and Muthusami et al [13]. Studies among the Bangladeshi, Pakistani and Malaysian population [14, 15, 16] are relevant to us as they are similar to the Indians in anthropomorphological aspects. The works of Hamida Khatun et al [17] in particular show similar results as us.

The different parameters of the kidneys as found in earlier works in India and Bangladesh are presented in Table 11 for comparative analysis with the present study:

Table 11: Comparison of present findings with previous studies

Parameters	Satheesh Naik, et al [12]	Hamida Khatun, et al [17]	Present Study
Mean Length	Left: 8.56 cm	8.99 cm	Left: 7.92 ± 0.66 cm
	Right: 8.02 cm		Right: 7.52 ± 0.64 cm
Mean Breadth	Left: 4.52 cm	4.08 cm	Left: 4.19 ± 0.45 cm
	Right: 4.56 cm		Right: 4.27 ± 0.41 cm
Mean Thickness	Left: 2.54 cm	1.78 cm	Left: 2.10 ± 0.39 cm
	Right: 2.51 cm		Right: 2.03 ± 0.40 cm
Mean weight	Left: 96.32 gm	92.08 gm	Left: 91.49 ± 7.49 gm
	Right: 86.88 gm		Right: 85.56 ± 6.26 gm

The left kidney has been typically found longer in various studies, including ours. This could be explained by the fact that the right kidney is associated with an enlarged right lobe of the liver and hence gets less space to grow.

5. Conclusion

A study on the different morphological parameters of the kidney and their variation among age groups and sexes is clinically important. It is of utmost importance to remember that the measurements of the kidney in an Indian person may not always reflect the standards quoted in the conventional textbooks. In such cases, the possibility of racial variations must be considered before looking for abnormalities. The treatment modalities of different diseases such as renal artery stenosis and the assessment of suitability in renal transplant cases are sometimes determined by the dimensions of the kidney. The findings of our study and studies like ours help to highlight the need for a nomogram of the kidney in the Indian population.

We also observed that the kidneys are indeed highly dynamic organs which continue growing up to as much as forty years of age. In old age, the kidneys shrink naturally due to glomerular and tubulo - interstitial changes in the renal cortex. A shrunken kidney in an elderly patient requires special consideration with regard to physiological changes before investigating for pathological causes. The female kidneys are smaller than the male kidneys. The dimorphic variations of the kidney plays a key role in determining the safe doses of drugs among other factors.

Since we performed our measurements on the cadavers brought to the mortuary for autopsy, we had to rely on the subjects' next of kin for the medical history, such as chronic diseases etc. Also, while we took a lot of care to exclude viscera or cadavers that started showing signs of putrefaction, we could not exclude the possibility of decomposition having started at a cellular level. Further detailed ventures, such as radiological measurement of the kidneys in live subjects and the correlation of the findings with a cadaveric study conducted in the same geographical area or among the same population may bring new information to light. We hope our present study will contribute to the progression of medical sciences.

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