

Gender wise comparison of right and left renal volume in eastern up population

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Abstract

Background: Renal volume is a comprehensive indicator of kidney size and varies with sex, laterality, ethnicity and anthropometric characteristics. Population-specific reference data are therefore necessary for accurate ultrasonographic interpretation.

Objective: To compare right and left renal volumes between males and females in the Eastern Uttar Pradesh population.

Materials and Methods: This hospital-based descriptive cross-sectional study included 1,000

apparently healthy adults aged 18–70 years from Eastern Uttar Pradesh. Bilateral renal ultrasonography was performed using a 3.5–5.0 MHz curvilinear transducer. Renal length, width and anteroposterior diameter were measured, and renal volume was calculated using the prolate ellipsoid formula. Data were summarized as frequency, percentage and mean $\pm$ standard deviation.

Results: The study included 508 males and 492 females. Overall mean renal length, width, anteroposterior diameter and volume were 9.69 ± 0.70 cm, 4.02 ± 0.47 cm, 3.49 ± 0.45 cm and 73.14 ± 21.41 cm³, respectively.

Mean right and left renal volumes were $66.42 \pm 19.56 \text{ cm}^3$ and $79.86 \pm 23.26 \text{ cm}^3$. In males, corresponding volumes were $71.66 \pm 20.74 \text{ cm}^3$ and $85.19 \pm 24.56 \text{ cm}^3$, whereas in females they were $61.00 \pm 16.60 \text{ cm}^3$ and $74.36 \pm 20.43 \text{ cm}^3$. All right–left and male–female renal-volume differences were statistically significant ($p < 0.001$).

Conclusion: Left renal volume was significantly greater than right renal volume in both sexes, while males had significantly greater bilateral renal volumes than females. These findings provide useful regional reference data for Eastern Uttar Pradesh.

Keywords: Kidney, Organ Size, Ultrasonography, Sex Factors, India.

Introduction

Renal size is an important morphological parameter in the evaluation and follow-up of renal disorders. Alterations in renal dimensions may accompany congenital abnormalities, urinary obstruction, infection, compensatory hypertrophy and acute or chronic parenchymal disease. Although renal length is routinely measured, it represents only one dimension of a structurally complex organ. Renal volume incorporates length, width and anteroposterior diameter and therefore provides a more comprehensive estimate of kidney size.¹ Ultrasonography is widely used for renal morphometry because it is non-invasive, inexpensive, readily available, repeatable and free from ionising radiation.² Renal volume is commonly estimated from three orthogonal measurements using an ellipsoid formula. Reliable volumetric assessment requires correct identification of the maximum renal axes, appropriate patient positioning and a standardised scanning protocol because volumetric estimates may show greater observer variability than linear measurements.³

Normal renal volume cannot be represented by a single universally applicable value. Renal dimensions vary with age, sex, laterality, height, body weight, body mass index and body surface area.⁴ The left kidney is commonly reported to be larger than the right, although the magnitude of this difference varies across populations.^{5,6} Multiple studies have also demonstrated side- and sex-related differences, with renal volumes generally being greater in males and on the left side.^{7,8} Ethnicity and geographical background may influence renal dimensions independently of anthropometric characteristics. Indian sonographic measurements differ from commonly cited international reference values, emphasising the need for population-specific renal nomograms.⁹ Recent North Indian evidence has demonstrated greater renal dimensions among males, left-sided predominance and correlations of renal size with height, weight and body surface area.¹⁰ In Uttar Pradesh, greater left renal length and greater bilateral renal length among males have been reported; however, the available study primarily assessed linear measurements in young adults.¹¹ Large-scale evidence comparing bilateral renal volumes between males and females in Eastern Uttar Pradesh remains limited. Applying reference values derived from geographically and anthropometrically different populations may result in misclassification of normal renal variation. The present study was therefore undertaken to compare right and left renal volumes between males and females and to describe overall renal dimensions in the Eastern Uttar Pradesh population. The findings may provide a regional reference for interpreting renal ultrasonography and support future clinical and epidemiological research.

Materials and Methods

This hospital-based descriptive cross-sectional study was conducted over a period of two years, in the Department of Anatomy, Madhav Prasad Tripathi Medical College, Siddharthnagar, Uttar Pradesh, in collaboration with the Department of Radiodiagnosis. Apparently healthy adults belonging to the Eastern Uttar Pradesh region were recruited using consecutive sampling. A total of 1000 participants were included, comprising 508 males and 492 females. Both kidneys were examined in every participant, providing measurements from 2000 renal units.

Adults aged 18–70 years, residing in Eastern Uttar Pradesh, with both kidneys present and normal renal morphology on ultrasonography were eligible for inclusion. Only participants who provided written informed consent were enrolled. Individuals with a history or sonographic evidence of congenital renal anomalies, solitary kidney, renal calculi, hydronephrosis, renal cysts, renal masses, cortical scarring, medical renal disease, previous renal surgery, nephrectomy or renal transplantation were excluded. Participants with diabetes mellitus, uncontrolled hypertension or another systemic condition likely to influence renal dimensions were also excluded. Pregnant women and individuals in whom either kidney could not be adequately visualized were not included.

Demographic information was recorded on a structured data-collection form. Participants were classified as male or female according to the sex recorded at enrolment. Bilateral renal ultrasonography was performed using a high-resolution ultrasound system equipped with a 3.5–5.0 MHz curvilinear transducer. All examinations were performed by an experienced radiologist using a uniform scanning protocol. Participants were initially examined

in the supine position and were subsequently placed in the right or left lateral decubitus position whenever required to improve visualization. The right and left kidneys were evaluated separately.

Renal length was measured in the longitudinal plane as the maximum bipolar distance between the superior and inferior renal poles. Renal width and anteroposterior diameter were measured in the transverse plane at the level of the renal hilum. Care was taken to obtain the maximum renal dimensions while avoiding oblique sections. All linear measurements were recorded in centimetres. Renal volume was calculated separately for each kidney using the prolate ellipsoid formula: renal volume (cm³) = renal length × renal width × anteroposterior diameter × 0.523.

The study variables included renal length, width, anteroposterior diameter and calculated renal volume. The primary outcome measures were the mean right and left renal volumes in males and females. Secondary outcomes included the overall mean renal dimensions and the descriptive differences in renal volume according to sex and laterality. Measurements were first summarized for the entire study population and were subsequently stratified by renal side and sex.

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics for Windows, version 25.0. Categorical variables were summarized as frequencies and percentages. Continuous variables were expressed as mean ± standard deviation. Right and left renal volumes measured in the same participants were compared using a paired-samples t-test. Male and female renal volumes were compared separately for each side using Welch's independent-samples t-test. All tests were two-sided, and $p < 0.05$ was considered statistically significant.

The study was conducted after obtaining approval from the Institutional Ethics Committee of Madhav Prasad Tripathi Medical College, Siddharthnagar. Written informed consent was obtained from each participant before enrolment. Participant identity remained confidential, and the study procedures were performed in accordance with the ethical principles of the Declaration of Helsinki.

Results

The study included 508 males (50.8%) and 492 females (49.2%). The nearly equal sex distribution ensured adequate representation of both groups for sex-wise renal-volume comparison.

Table 1: Distribution of the study population according to sex (N = 1000)

Sex	Number of participants (n)	Percentage (%)
Male	508	50.8
Female	492	49.2
Total	1000	100.0

The overall mean renal length, width and anteroposterior diameter were 9.69 ± 0.70 cm, 4.02 ± 0.47 cm and 3.49 ± 0.45 cm, respectively. The mean renal volume was 73.14 ± 21.41 cm³.

Table 2. Overall renal dimensions in the study population (N = 1000)

Renal parameter	Mean $\pm$ SD
Length (cm)	9.69 ± 0.70
Width (cm)	4.02 ± 0.47
Anteroposterior diameter (cm)	3.49 ± 0.45
Renal volume (cm ³)	73.14 ± 21.41

The mean left renal volume (79.86 ± 23.26 cm³) was greater than the mean right renal volume (66.42 ± 19.56

cm³). The observed mean right–left difference was 13.44 cm³, indicating left-sided predominance.

Table 3. Overall right and left renal volumes in the study population (N = 1000)

Renal side	Renal volume (cm ³), mean $\pm$ SD
Right kidney	66.42 ± 19.56
Left kidney	79.86 ± 23.26

Males had greater renal volumes than females for both the right kidney (71.66 ± 20.74 versus 61.00 ± 16.60 cm³) and left kidney (85.19 ± 24.56 versus 74.36 ± 20.43 cm³). Within both sexes, the left renal volume was greater than the right.

Table 4: Sex-wise comparison of right and left renal volumes

Sex	Number of participants (n)	Right renal volume (cm ³), mean $\pm$ SD	Left renal volume (cm ³), mean $\pm$ SD	P value
Male	508	71.66 ± 20.74	85.19 ± 24.56	<0.001
Female	492	61.00 ± 16.60	74.36 ± 20.43	<0.001

Left renal volume was significantly greater than right renal volume in the overall population and within both sexes. Males had significantly greater right and left renal volumes than females. All observed differences were statistically significant at $p < 0.001$.

Table 5. Consolidated pattern of renal volume according to sex and laterality

Comparison	First group, mean $\pm$ SD (cm ³)	Second group, mean $\pm$ SD (cm ³)	Mean difference (cm ³)	Test applied	p value	Observed pattern
Overall: left versus right	79.86 $\pm$ 23.26	66.42 $\pm$ 19.56	13.44	Paired t-test†	<0.001	Left renal volume was greater
Male: left versus right	85.19 $\pm$ 24.56	71.66 $\pm$ 20.74	13.53	Paired t-test†	<0.001	Left renal volume was greater among males
Female: left versus right	74.36 $\pm$ 20.43	61.00 $\pm$ 16.60	13.36	Paired t-test†	<0.001	Left renal volume was greater among females
Right kidney: male versus female	71.66 $\pm$ 20.74	61.00 $\pm$ 16.60	10.66	Welch independent t- test	<0.001	Male right renal volume was greater
Left kidney: male versus female	85.19 $\pm$ 24.56	74.36 $\pm$ 20.43	10.83	Welch independent t- test	<0.001	Male left renal volume was greater

The mean left renal volume was significantly greater than the right renal volume in the overall population and separately among males and females (all $p < 0.001$). Males had significantly greater right and left renal volumes than females (both $p < 0.001$).

Discussion

The present study evaluated renal dimensions and sex-related variations in renal volume among 1000 individuals from the Eastern Uttar Pradesh population, comprising 508 males and 492 females. The overall mean renal length, width, anteroposterior diameter and renal volume were 9.69 ± 0.70 cm, 4.02 ± 0.47 cm, 3.49 ± 0.45 cm and 73.14 ± 21.41 cm³, respectively. The principal findings were that the left kidney had a greater mean volume than the right kidney and that both renal volumes were greater in males than in females.

The overall renal dimensions observed in the present study were generally lower than those reported in previous populations. In a Pakistani study of 194 participants, Buchholz et al. reported a mean renal length of 10.4 ± 0.8 cm, width of 4.5 ± 0.6 cm, anteroposterior dimension of 1.6 ± 0.2 cm and renal volume of 76.16 ± 21.7 cm³.⁶ The renal length and width in that study were slightly greater than those observed in the present study, while the difference in overall renal volume was relatively small. Rathore et al., in an Indian study of 151 participants, reported a mean renal length of 10.86 ± 1.23 cm, width of 5.13 ± 0.77 cm, anteroposterior diameter of 4.73 ± 0.95 cm and renal volume of 137.54 ± 34.48 cm³.¹² Kang et al. reported corresponding values of 11.08 ± 0.96 cm, 6.23 ± 0.65 cm, 4.73 ± 0.67 cm and 158.7 ± 62.9 cm³ in a Korean study of 125 participants.¹³

Maravi et al. documented an overall mean renal volume of 111.28 cm³ among 105 Indian participants.¹⁴ Thus, the mean renal volume recorded in the present study was lower than those reported by Rathore et al.¹², Kang et al.¹³ and Maravi et al.¹⁴

A distinct difference between the right and left renal volumes was observed in the present population. The mean right renal volume was 66.42 ± 19.56 cm³, whereas the mean left renal volume was 79.86 ± 23.26 cm³. A similar left-sided predominance has been documented in several populations. Egberongbe et al. reported mean right and left renal volumes of 106.14 ± 25.42 cm³ and 114.06 ± 29.78 cm³, respectively, in a southwestern Nigerian population.¹⁵ Okur et al. reported corresponding values of 158 ± 39 cm³ and 168 ± 40 cm³ among 152 Turkish participants.¹⁶ Rathore et al. documented mean right and left renal volumes of 137.54 ± 34.48 cm³ and 138.22 ± 29.81 cm³, respectively.¹² Similarly, Maravi et al. reported right and left renal volumes of 109.70 cm³ and 110.97 cm³, respectively.¹⁴ Although the absolute renal volumes in these studies were higher than those in the present study, their laterality pattern was broadly consistent, with the left kidney generally demonstrating a greater mean volume than the right.

Sex-wise analysis showed that males had greater renal volumes than females on both sides. Among the 508 males, the mean right and left renal volumes were 71.66 ± 20.74 cm³ and 85.19 ± 24.56 cm³, respectively. Egberongbe et al. reported corresponding male renal volumes of 112.98 ± 25.56 cm³ and 123.11 ± 32.49 cm³.¹⁵ In the Turkish study by Okur et al., the mean right and left renal volumes among 73 males were 164.3 ± 38 cm³ and 175.8 ± 41 cm³, respectively.¹⁶ Rathore et al. reported right and left renal volumes of 143.94 ± 35.69

cm³ and 142.94 ± 30.48 cm³, respectively, among 95 males.¹² Bhardwaj et al. documented corresponding male renal volumes of 110 ± 28 cm³ and 112.3 ± 27 cm³.¹⁷ Maravi et al. reported right and left renal volumes of 118.71 cm³ and 119.16 cm³, respectively, among 52 males.¹⁴ Therefore, although the male renal volumes in the present study were lower than those reported previously, the predominance of the left renal volume was consistent with most comparison studies. Rathore et al. represented a minor exception, with a marginally greater right renal volume among males.¹²

Among the 492 females, the mean right renal volume was 61.00 ± 16.60 cm³ and the mean left renal volume was 74.36 ± 20.43 cm³. Egberongbe et al. reported female right and left renal volumes of 99.31 ± 23.07 cm³ and 105.01 ± 23.77 cm³, respectively.¹⁵ Okur et al. reported corresponding values of 151.8 ± 39 cm³ and 159.8 ± 37 cm³ among 79 females.¹⁶ Rathore et al. documented mean right and left renal volumes of 126.67 ± 30.16 cm³ and 130.20 ± 27.07 cm³, respectively, among 56 females.¹² Bhardwaj et al. reported corresponding volumes of 95 ± 23.1 cm³ and 99.3 ± 24 cm³.¹⁷ Maravi et al. observed right and left renal volumes of 102.59 cm³ and 104.66 cm³, respectively, among 53 females.¹⁴ The left-sided predominance observed among females in the present study was therefore consistent with all the cited comparison studies.

The sex-related pattern identified in this study was also concordant with previous findings. In the present population, males had greater mean renal volumes than females for both the right kidney (71.66 ± 20.74 versus 61.00 ± 16.60 cm³) and the left kidney (85.19 ± 24.56 versus 74.36 ± 20.43 cm³). Comparable male predominance was reported by Egberongbe et al.¹⁵, Okur et al.¹⁶, Rathore et al.¹², Bhardwaj et al.¹⁷ and Maravi et

al.¹⁴ The male predominance in bilateral renal volume was statistically significant, as were the right-left differences observed in the overall population and within both sexes (all $p < 0.001$).

The lower absolute renal volumes in the present study compared with most previous studies may reflect differences in ethnicity, geographical background, body habitus, participant selection, imaging modality, measurement protocol and the formula used to estimate renal volume. These factors should be considered when renal dimensions derived from one population are applied to another. The large sample size of the present study provides important population-specific data for Eastern Uttar Pradesh and reinforces the need for locally derived renal reference values. Overall, the study demonstrates a consistent anatomical pattern of greater left renal volume and greater bilateral renal volumes among males, while also indicating that renal volumes in this population are lower than those reported in several Indian and international studies.

Conclusion

By defining the renal volumetric profile of Eastern Uttar Pradesh, this study provides an important regional anatomical reference derived from 1,000 individuals. The mean left renal volume was significantly greater than the right renal volume in the overall population and in both sexes. Males demonstrated significantly greater bilateral renal volumes than females, whereas the overall mean renal volume was lower than values reported in several Indian and international studies. These findings highlight clinically relevant variation according to renal side and sex. The derived measurements may thereby strengthen ultrasonographic interpretation and facilitate more accurate recognition of abnormal renal size in routine clinical practice.

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