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Morphometry of Adult Kidney and Arrangement of Structures at the Hilum: A Cadaveric Study

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ABSTRACT

Introduction

Renal dimensions and weight are important indicators of kidney function. This study aimed to assess renal dimensions, weight, lobulation, and variations in hilar pattern, and to compare these parameters between the right and left kidneys.

Methods

A descriptive cross-sectional study was conducted on 124 pairs of morphologically normal kidneys obtained from adult cadavers of the Department of Forensic Medicine, Maharajgunj Medical Campus. Renal length, breadth, thickness, and weight were measured. Lobulation and antero-posterior arrangement of structures at the hilar structures were assessed.

Results

Among 124 cadavers, 82 were male, and 42 were female. The age ranged from 18 to 81 years, with a mean age of 38.06±15.35 years. The mean weight of kidney was 124.71±23.96 g in males and 110.63±24.33 g in females. The mean weight of the kidney was 116.65±24.46 g (right) and 123.25±26.72 g (left). The median length was 10.04 cm (right) and 10.43 cm (left). The median breadth was 5.56 cm (right) and 5.61 cm (left). The median thickness was 2.81 cm (right) and 3.05 cm (left). Lobulation was observed in 8% of right and 16% of left kidneys. The typical pattern of hilar arrangement was seen in 56.5 % of right kidneys and 49.2% of left kidneys.

Conclusion

The left kidney was greater in length, breadth, thickness, and weight than the right. Renal dimensions were higher in males. Lobulation and variations in hilar arrangement were more frequent on the left side.

Keywords

Kidney; lobulations; renal vessels; transplantation

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INTRODUCTION

Renal dimensions and weight correlate with kidney function, including serum creatinine concentration and creatinine clearance.[1] Each kidney is bean-shaped and measures approximately 11 cm in length, 6 cm in breadth, and 3 cm in anteroposterior dimension.[2] The left kidney is slightly longer and narrower than the right kidney.[2] The average weight of an adult kidney is about 150 g in males and 135 g in females.[2]

Nephron-sparing surgeries use minimally invasive techniques, and for this, accurate knowledge of normal as well as variant anatomy of the renal vascular pedicle is important.[3] The typical anteroposterior arrangement of the renal hilar structures consists of the renal vein anteriorly, the renal artery in the intermediate position, and the renal pelvis posteriorly.[2] Knowledge of renal dimensions, hilar structure, and their variations is essential for transplant surgeons, urologists, and radiologists during renal surgery, transplantation and radiological procedures.[4]

Small accessory arteries may be missed on Spiral Computed Tomographic Angiography (SCTA), and are sometimes identified only during live nephrectomies.[5] In settings where cadaveric transplantation of the kidney is permitted[5], this study provides valuable baseline anatomical information about adult Nepalese kidneys. This study aimed to assess the morphometric parameters of the freshly autopsied kidneys of adult Nepalese individuals, examine the lobulations and variations in renal hilar arrangement patterns, and compare the renal dimensions between males and females as well as between the left and right sides.

METHODS

This cadaveric descriptive cross-sectional study was conducted at the Department of Forensic Medicine, Maharajgunj Medical Campus, Tribhuvan University Teaching Hospital. Non- probability sampling method was applied and the study was conducted from May 8th, 2022, to April 13th, 2023, after ethical approval was taken from the Institutional Review Committee of the Institute of Medicine with the reference number 403(6-11)-E2/078/079.

Sample size was calculated using the formula:

$$n = (\frac{Z\sigma}{E})^2$$

Where Z=confidence level corresponding to the level of confidence 95%=1.96

σ=expected SD as per previous studies=0.283 [6]
E=absolute error 5%=0.05

n=sample size

Thus, 124 cadavers (248 kidneys) were included in the study, where Nepalese cadavers above 18 years of age were set as the inclusion criteria, while putrefied cadavers and specimens with gross pathological defects such as hematoma, cysts, or tumours were set as exclusion criteria.

Written informed consent was obtained from the relatives of the deceased prior to the data collection. Precautionary measures were taken, including wearing protective gear like gloves, a mask, a face shield and a surgical gown. Preliminary skin incision was given, and whole pluck/en masse dissection was done by Letulle's method. The kidneys were dissected from the posterior abdominal wall by retracting them anteromedially, with one hand protecting, while the other hand performed a combination of forceful blunt dissection and knife cuts to release the lateral and posterior attachments. Medially, the kidneys were freed by transecting the renal vessels and the upper ureter. A similar method of dissection was applied on the other side.[7]

After removal of the kidneys, they were thoroughly washed in running water and cleaned with a sponge to remove the residual blood. Specimens were taken in a tray, and both kidneys of each side were placed in the respective sides of the tray. The perinephric fat and renal fascia were removed, taking care to preserve the hilar structures. Measurements were then obtained.

The length, breadth, and thickness of both kidneys were measured using digital vernier calipers in centimetres. The maximum distance between the superior and inferior poles of the kidney was recorded as the length, the greatest distance between the medial and lateral borders at the same level was taken as the breadth, and the maximum anteroposterior diameter was considered the thickness of the kidney.[8] The weight of both

kidneys was measured in grams using an electronic weighing machine.

The anteroposterior arrangement of hilar structures on both kidneys was examined 0.5 cm from the anterior lip of the hilum, considering only the renal artery, renal vein, and renal pelvis.[9] Any variations in their arrangement were recorded. Data were entered in the Microsoft Excel Worksheet, and samples with incomplete data were excluded. Statistical analysis was performed using SPSS version 26. Descriptive statistics were calculated, and the Shapiro-Wilk test was used to assess the normality of the data. Based on the normality assessment, differences between males and females, as well as between the right and left kidneys, were analysed using independent sample t-tests and Wilcoxon signed-rank tests. The statistical significance was set at $p < 0.05$ with a 95% confidence interval.

RESULTS

A total of 124 cadavers were studied, of which 82 (66.1%) were male and 42 (33.9%) were female. The cadavers ranged in age from 18 to 81 years, with a mean age of 38.06±15.35 years. A total of 248 kidneys were obtained, comprising 124 right kidneys and 124 left kidneys.

Mean length, breadth, thickness, and weight of the right and left kidneys are shown in **Table 1**.

Table 1. Descriptive statistics of the measurements of right and left kidney and their weight

Side	Parameters	Minimum	Maximum	Mean	Std. Deviation
Right	Length (cm)	7.08	12.45	10.04	0.84
	Breadth (cm)	3.48	6.97	5.53	0.65
	Thickness (cm)	1.35	4.37	2.87	0.49
	Weight (g)	54.9	188.6	116.65	24.46
Left	Length (cm)	7.01	12.91	10.43	0.93
	Breadth (cm)	2.93	7.28	5.54	0.68
	Thickness (cm)	1.37	4.68	3.07	0.54
	Weight (g)	51.0	201.7	123.25	26.73

The non-parametric test Wilcoxon signed-rank test, was conducted to compare the measurements of the right and left kidneys. As shown in Table 2, the median length of the left kidney was greater than that of the right, and the difference was statistically significant ($p < 0.001$). The median breadth of the left kidney was also greater than that of the right; however, this difference was not statistically significant ($p = 0.906$). The median thickness of the left kidney was greater than that of the right, and the difference was statistically significant ($p < 0.001$).

Table 2. Comparison between the dimensions of the right and left kidneys

Parameters	Side	Median	Interquartile range (IQR)	Significance (p- value)
Length (cm)	Right kidney	10.04	0.90	< 0.001[a]
	Left kidney	10.43	1.15	
Breadth (cm)	Right kidney	5.56	0.86	0.906[a]
	Left kidney	5.61	0.92	
Thickness (cm)	Right kidney	2.81	0.65	< 0.001[a]
	Left kidney	3.05	0.65	

[a] Wilcoxon Rank Test

The median average length of the kidney in males was 10.27 cm, and in females, it was 10.06 cm. Although the median length in males was greater than in females, the difference was not statistically significant ($p = 0.569$). The median average breadth of the kidney in males was 5.71 cm, compared to 5.23 cm in females; this difference was statistically significant ($p = 0.01$). The mean average thickness of the kidney was 3.03 ± 0.50 cm in males and 2.86

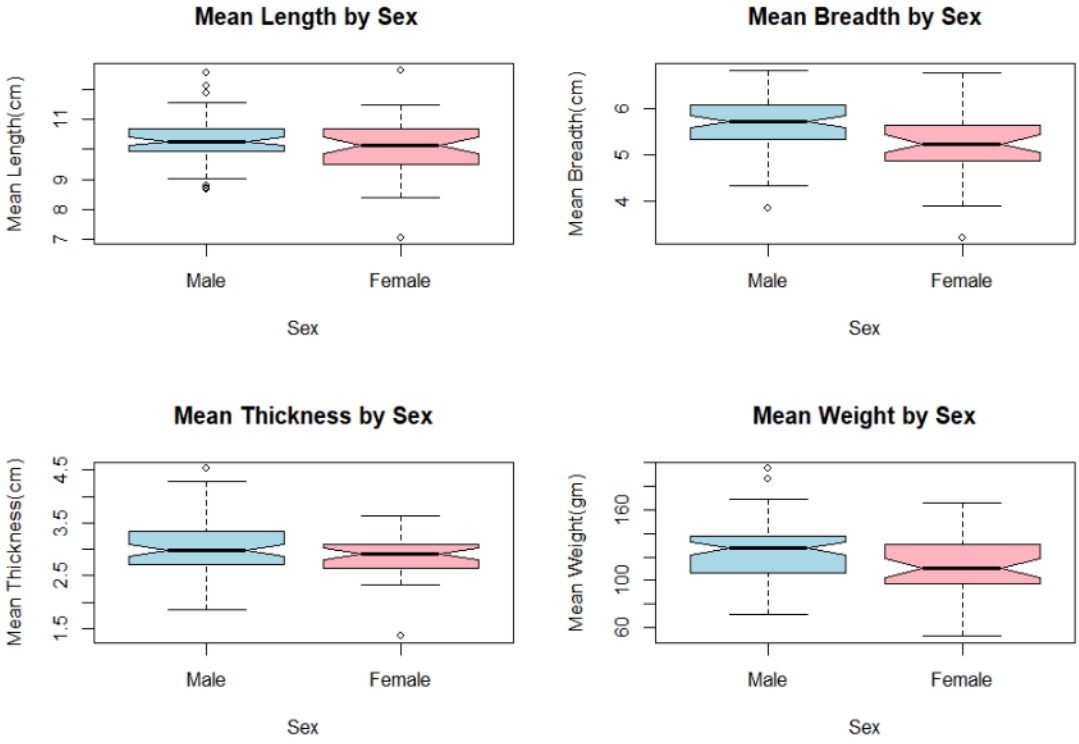

Figure 1. Comparison of the dimensions and weight of kidneys in males and females

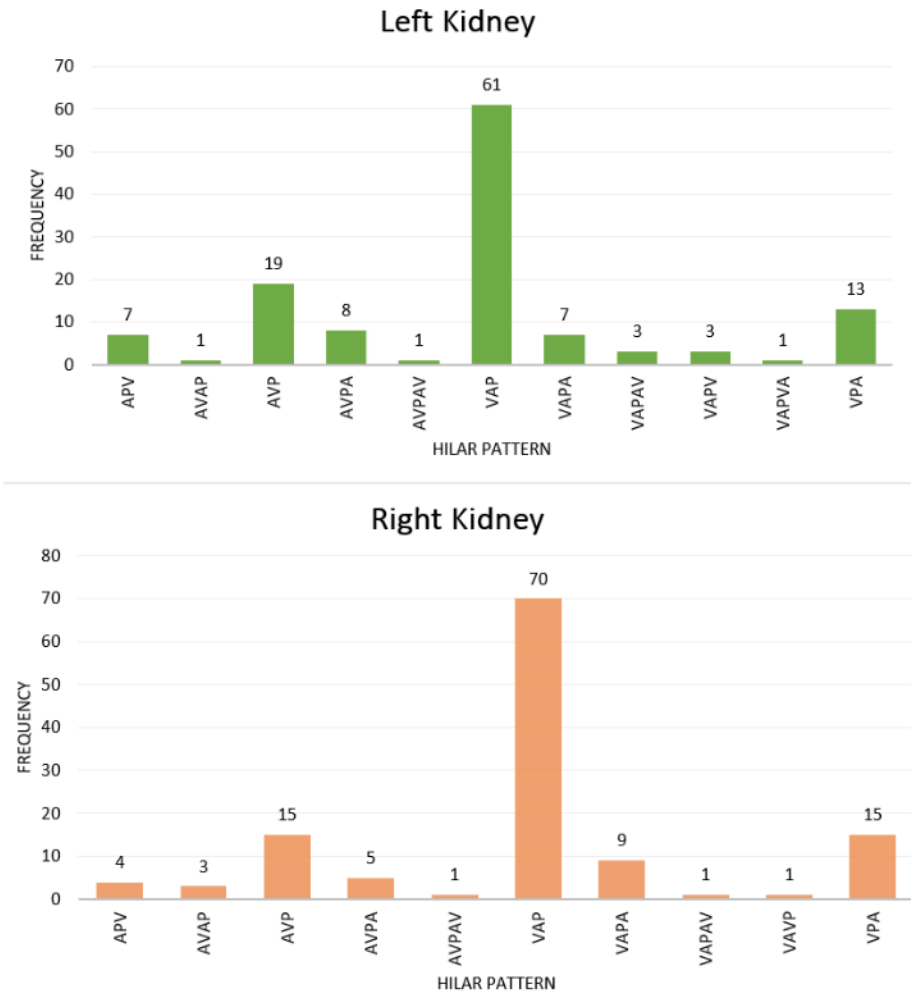

Figure 2. Bar diagram showing the hilar pattern of right and left kidneys

± 0.39 cm in females. The mean thickness in males was greater than in females, and the difference was statistically significant (p = 0.05). A comparison of renal dimensions and weight between males and females is shown in **Figure 1**.

Out of 124 cadavers, lobulation was present in 15 cases (12.1%). Bilateral lobulation was observed in six cases (4.8%), while unilateral lobulation was present in nine cases (7.3%) of left kidneys. No cases of lobulation were observed in the right kidney alone. The arrangement of renal hilar structures showed considerable variation at the hilum. A total of 10 patterns of hilar arrangement were observed in the right kidneys, whereas the left kidney exhibited 11 different patterns. The arrangement of hilar structures and their percentages are shown in **Figure 2.**

(APV- Renal artery-pelvis-renal vein; AVAP- Anterior division of renal artery-vein-posterior division of renal artery-pelvis; AVP- Renal artery-renal vein-pelvis; AVPA-Anterior division of renal artery-renal vein-pelvis-posterior division of renal artery; AVPAV- Anterior division of renal artery-anterior tributary of renal vein-pelvis-posterior division of renal artery-posterior tributary of renal vein; VAP- Renal vein-renal artery-pelvis; VAPA- Renal vein-anterior division of renal artery-pelvis-posterior division of renal artery; VAPAV- Anterior tributary of renal vein-anterior division of renal artery-pelvis-posterior division of renal artery-posterior tributary of renal vein; VAPV- Anterior tributary of renal vein-artery-pelvis-posterior tributary of renal vein; VAPVA- Anterior tributary of renal vein-anterior division of renal artery-pelvis-posterior tributary of renal vein-posterior division of renal artery; VAVP- Anterior tributary of renal vein-renal artery-posterior tributary of renal vein-pelvis; VPA- Renal vein-pelvis-renal artery.)

DISCUSSION

The present study found the mean weight of kidney to be 124.71 ± 23.96 g in males and 110.63 ± 24.33 g in females. The median length, breadth, and thickness of the right kidney were 10.04 cm, 5.56 cm and 2.81 cm, respectively and those of the left kidney were 10.43 cm, 5.61 cm and 3.05 cm, respectively. Lobulation was observed in 8% of right kidney specimens and 16% of left kidney specimens. 10 types of patterns of arrangement of renal hilar structures were observed in right kidneys, and 11 patterns were observed in left kidneys. The normal hilar arrangement (VAP) was observed in 56.5 % of right kidneys and 49.2% of left kidneys.

Renal dimensions in males were higher than in females, consistent with findings by Shambharkar[8], Anibor[10], and Dharmadas[6], possibly due to longer male growth spurts. However, the deviation of renal weight from standard textbook values and reports from Bangladeshi[11], Iranian[12], and Turkish[13] populations might be due to differences in sample size, age distribution, sex composition, and regional variation.

The left kidney showed greater weight and dimensions than the right kidney, correlating with textbook values[2] and previous studies[14–17]. This is because of the presence of the liver on the right side that limits the growth of the right kidney[10], and relatively better perfusion of the left kidney.

The fetal lobulation was more frequently observed on the left side. Although lobulation is a normal developmental remnant, it may be misinterpreted as pathological scarring, or mass lesions in diagnostic imaging.[18]

Multiple variations in the arrangement of renal hilar structures were identified on both sides, with greater variability on the left side, consistent with previous studies of Trivedi[3], Pereira-Correia[19], Varalakshmi[20], and Soman[21]. This could be attributed to the developmental difference in renal vasculature.

The findings of this study have significant clinical and surgical implications. Renal morphometric data provide baseline reference values for anatomists, radiologists, and surgeons, and are useful in assessing renal function, disease, and transplant suitability. In addition, greater kidney length has been associated with higher cardiovascular risk and mortality in high-risk patients, suggesting its potential as a clinical marker.[22] Variations in hilar anatomy are of surgical relevance as they may influence operative approaches in laparoscopic surgery, renal transplantation, and also during radiological evaluation. Furthermore, awareness of persistent fetal lobulation helps avoid diagnostic errors.

This was a cadaveric study, therefore, the measurements may not fully reflect in vivo

conditions. The lack of clinical history and information on comorbidities may have influenced renal size, and such associations could not be established. Additionally, the relationship between kidney size and body parameters such as height and body mass index could not be evaluated.

Future studies with larger, more diverse populations and inclusion of anthropometric parameters are recommended. Including clinical history and comorbidities would help establish an association with pathological conditions. Evaluation of variations in renal vascular anatomy, along with measurements of artery length and diameter, would provide valuable insights, particularly for surgical and interventional procedures.

CONCLUSION

The morphometry of the left kidney was greater than that of the right in length, breadth, thickness, and weight. Renal dimensions were higher in males. Lobulation was more frequently observed on the left side. Multiple patterns of hilar arrangement were observed in both kidneys, predominantly in the left. These findings may serve as a reference for anatomical assessment and support radiological and surgical evaluation of the kidney.

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CONFLICT OF INTEREST

The author(s) declare that they have no conflicts of interest related to the research, authorship, or publication of this article.

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