E-3050-9610
P-2795-3270



GPH INTERNATIONAL JOURNAL
Research in
Biological Science
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10.5281/ZENODO.17286830 VOL. 08 ISSUE 09 SEPT - 2025 ARTICLE ID: #02102

Comparative Analysis of Morphological and Histological Differences between Right and Left Human Kidneys

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Conflict of interest: No

Funding: Self-funding

IRB-*SCMST/DPT/IRB-10/08-001*
Human Ethics and Consent to Participate declarations: not applicable

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Abstract

Background: The right and left human kidneys are both bilateral organs, but they don't always have the same structure and histology. These kinds of differences can have an impact on how the kidneys work, how surgery is done, and how a diagnosis is made. Researchers in Western countries have looked into these kinds of differences a lot, but not so much in South Asia, especially Bangladesh. It is important to know about these changes in structure and histology because chronic kidney disease (CKD) is becoming more common in the area. **Objective:** The goal of this study was to look at the differences in shape and structure between the right and left human kidneys in different age groups using cadaver samples from Bangladesh.

Method and Material: We used purposive sampling to get 100 kidneys (50 right and 50 left) from unclaimed bodies at Dhaka Medical College and did a descriptive cross-sectional study on them. We put the kidneys in 10% formalin and split them into four age groups: 10 to 19 years, 20 to 39 years, 40 to 59 years, and 60 years or older. The goal of this study is to look at the differences in shape and structure between the right and left human kidneys in different age groups, using cadaveric samples from Bangladesh. We did a descriptive cross-sectional study on 100 kidneys (50 right and 50 left) that we got from unclaimed bodies at Dhaka Medical College through purposive sampling. The kidneys were kept in 10% formalin and split into four age groups: 10 to 19 years, 20 to 39 years, 40 to 59 years, and 60 years or older. The concern was taken by all sample. **Results:** The results of this study could help us learn more about how kidneys age and what that might mean for medical practice. We used microscopy and staining methods to look at morphometric features (weight, length, width, thickness, and volume) and histological features (the number and size of glomeruli per mm^2). We looked at the data with ANOVA and unpaired t-tests. Results: The 20–39 age group had the biggest kidneys and the most glomeruli. The number of glomeruli went down a lot as people got older, but their size went up, which could be a sign of compensatory hypertrophy. The left kidney was always bigger than the right in terms of weight, length, and volume. There were statistically significant changes in structure between the right and left kidneys and between age groups. These results show how important it is for the kidneys to be on the same side and how they change shape as we get older. **Conclusion:** This study shows that the right and left kidneys have very different structures and histologies, and that they get worse with age, especially after age 60. The results give South Asia some important baseline information and show how important it is for nephrologists, surgeons, and transplant surgeons to know about the area's anatomy. In the future, researchers should use molecular imaging and spatial profiling to learn more about the functional implications.

Keywords:

Renal Laterality, Kidney Morphometry, Glomerular Density, Histological Asymmetry, South Asia.

***How to cite*:** Zahan, A., Yesmin, F., Mahmood, S., Akhi, S., Fokhruzzaman, M., Sultana, R., Meem, J., Mawa, Z., Halder, S., & Afridi, S. (2025). Comparative Analysis of Morphological and Histological Differences between Right and Left Human Kidneys. *GPH-International Journal of Biological & Medicine Science*, 8(9), 15-29. https://doi.org/10.5281/zenodo.17286830

Background:

The kidneys are important organs that help keep the body in balance by controlling the levels of fluids, electrolytes, and waste. The right and left human kidneys are on opposite sides of the body, but they may have small differences in shape and tissue structure that could be useful for scientific and clinical purposes. Researchers have found that these differences can be very important for planning surgeries, finding kidney problems, and doing transplants in both animals and people [1,2]. Cadaveric and imaging-based studies have shown for a long time that the renal vasculature and cortical-medullary structures are not always the same [7]. For instance, up to 30% of people in Western countries have renal arteries that are different in number, branching pattern, and origin [7]. There aren't many studies like this in South Asia, especially in Bangladesh and the areas around it. This shows that there isn't enough anatomical data for that area. There have also been changes between species, which shows that evolution and function are not the same for all species [3,10]. Histological comparisons show that the kidneys have different densities of nephrons, thicknesses of the cortex, and shapes of the glomeruli. Age, systemic disease, and embryonic development can all have an effect on these differences [5,12]. Jayapandian et al. created deep learning algorithms to measure these differences. These algorithms have made it easier to tell the difference between histologic structures in human kidney cortices [5]. This is especially important because the number of people with chronic kidney disease (CKD) is rising around the world. The overall rate is 9.1%, but it is higher in Europe (11–13%) and South Asia (10–11%) because of diabetes and high blood pressure [4,6]. Scientists have learned a lot about how kidneys work and how they are built by testing them on pigs and rats. In many ways, these animals are like and unlike people [2,8,9]. Maurya et al. said that these similarities between species' kidneys are important for translational nephrology research [1]. Making kidney organoids has also started a new era in tissue modeling and regenerative medicine. It has helped us learn more about how organs form and possible histological asymmetries [13]. There are more and more people in Bangladesh with chronic kidney disease (CKD). This makes it harder to diagnose because there aren't many modern imaging and histological assessment methods available. This means that more research needs to be done in some areas to help with clinical interventions. We can learn a lot from Western literature, but there isn't much anatomical-histological kidney data that is specific to South Asia, so we need to do more research [4,7]. This study wants to do a thorough comparison of the structural and histological differences between the right and left human kidneys because renal asymmetry is important in surgeries

like laparoscopic nephrectomy, transplantation, and radiologic interpretation. This study uses both anatomical and histological methods to give a full understanding that is useful for both academic purposes and therapy.

Methodology

This cross-sectional descriptive study took place at the Department of Anatomy at Rajshahi Medical College in Bangladesh. It used 100 cadaveric kidneys (50 right and 50 left) that were collected through purposive non-random sampling from unclaimed dead at Dhaka Medical College's morgue. The kidneys that may be included had to be from both men and women and not have any congenital defects, be decaying, be missing on one side, have had trauma, have renal diseases, or have died from poisoning. We put the samples into four age groups (Group A: 10–19, Group B: 20–39, Group C: 40–59, and Group D: 60 years or older) and kept them in 10% formalin for morphometric and histological investigation. We used light microscopy, ocular/stage micrometers, and standardized staining techniques to look at the glomerular count (per mm^2) and diameter. We also used morphometric parameters including weight, length, width, thickness, and renal volume (estimated using the ellipsoid formula). We got permission from an ethics board and then used SPSS v16.0 to look at the data using ANOVA and unpaired t-tests. Some of the problems with the study were that the sample was small and not evenly distributed, there wasn't enough time, there wasn't enough analysis based on sex, there wasn't enough coverage of all age groups, and there weren't enough specimens available. These issues could have made the results less generalizable. The study's goal was to gather basic anatomical and histological information about the size and structure of kidneys in people of all ages. The edical concent was taken from IRB team of Saic College of Medical Science and Technology (SCMST) and from all the sample.

Results

The study looks at the number and size of glomeruli and the structural dimensions (weight, length, breadth, thickness, and volume) of both kidneys in people of different ages (A: 10–19, B: 20–39, C: 40–59, D: ≥60 years).

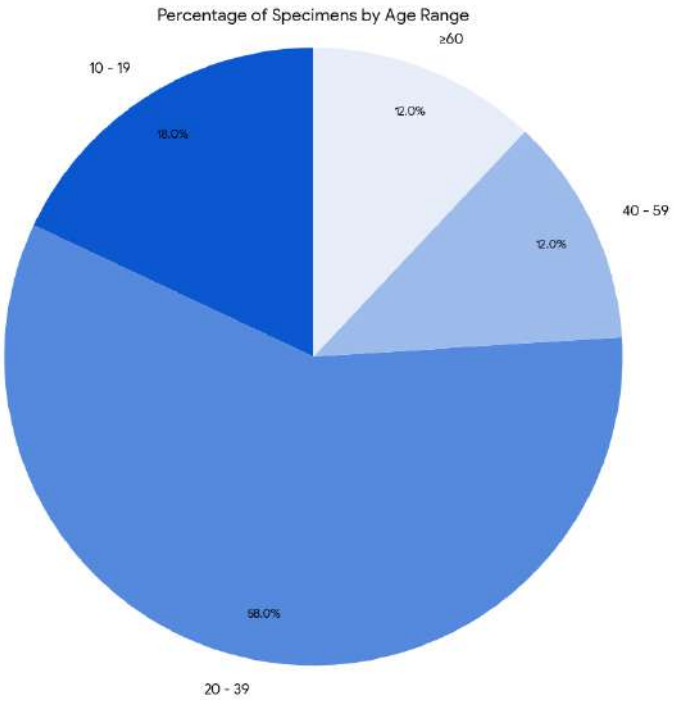


Figure 1: Age distribution.

Table 1 shows that the number of glomeruli per mm² was highest in the 20–39 age group: 9.33 ± 0.46 for the left kidney and 9.27 ± 0.44 for the right kidney. ANOVA showed that there were significant differences between age groups (Left: F=22.062, p=0.001; Right: F=17.427, p=0.001). The size of the glomeruli likewise peaked in the same age group: 153.01 ± 1.52 μm (Left) and 153.06 ± 1.73 μm (Right).

Variable	**Kidney**	**Age Group**	**N**	**Mean**	**SD**	**95% Confidence Interval**		**ANOVA Results**
						Lower Value	Upper Value	Between Groups Sum of Squares / df / Mean Squares / F / Sig.
Number of Glomeruli (per mm²)	Left	A (10-19)	5	8.48	0.18	8.24	8.71	4.294 / 1 / 4.294 / 22.062 / 0.001
		B (20-39)	5	9.33	0.46	9.00	9.66	
		C (40-59)	5	8.20	0.39	7.71	8.68	

		D (≥60)	5	7.85	0.15	7.69	8.00	
Number of Glomeruli (per mm²)	Right	A (10-19)	5	8.35	0.20	8.10	8.61	3.367 / 1 / 3.367 / 17.427 / 0.001
		B (20-39)	5	9.27	0.44	8.95	9.59	
		C (40-59)	5	8.27	0.42	7.74	8.79	
		D (≥60)	5	7.78	0.19	7.57	7.98	
Size of Glomeruli (µm)	Left	A (10-19)	5	140.89	4.13	135.75	146.03	493.615 / 1 / 493.615 / 287.45 / 0.001
		B (20-39)	5	153.01	1.52	151.84	154.01	
		C (40-59)	5	140.76	0.61	139.99	141.52	
		D (≥60)	5	138.34	0.77	137.52	139.15	
Size of Glomeruli (µm)	Right	A (10-19)	5	141.65	4.24	136.37	146.92	480.480 / 1 / 480.480 / 217.85 / 0.001
		B (20-39)	5	153.06	1.73	151.82	154.30	
		C (40-59)	5	141.06	0.64	140.26	141.85	
		D (≥60)	5	138.56	0.73	137.79	139.33	

Table1: combining the number and size of glomeruli for both the left and right kidneys across the different age groups, including means, standard deviations, 95% confidence intervals, and ANOVA test results.

The ANOVA results were again very significant (Left: F=287.45, p=0.001; Right: F=217.85, p=0.001). The left kidney had slightly higher average values than the right kidney, as shown in Table 2: weight 98.67 ± 3.95g, length 9.56 ± 0.98cm, breadth 4.16 ± 0.44cm, thickness 3.28 ± 0.40cm, and volume 58.18 ± 9.35cm³.

Average measurement	Left Kidney	Right Kidney
Weight	98.67 ± 3.95gm	95.80± 7.05gm
Length	9.56 ± .98cm	9.41± 1.03cm
Breadth	4.16±.44cm	3.95±.57cm
Thickness	3.28±.40cm	3.27±.30cm
Volume	58.18±9.35cm^3	57.67±17.86cm^3
Number of glomeruli	9.33±.46 permm^2	9.27±.44 permm^2
Size of glomeruli	153.01±1.52µm	153.06±1.73µm

Table 2: Comparison between left and right kidney in all dimensions (Highest values).

The right kidney had 95.80 ± 7.05g, 9.41 ± 1.03cm, 3.95 ± 0.57cm, 3.27 ± 0.30cm, and 57.67 ± 17.86cm³. Using independent t-tests, Table 3 shows a summary of the statistical comparisons of these dimensions between different age groups. There were big differences in weight between A and B (Left: t=3.604, p=0.001; Right: t=95.871, p=0.001) and A and C (Left: t=105.355, p=0.001; Right: t=94.128, p=0.001). There was no big difference between A and D (p=0.50). There was a big difference in length between A and B (Left: t=0.040, p=0.001; Right: t=0.008, p=0.001) and B and D (Left: t=0.496, p=0.001; Right: t=0.075, p=0.001), but not between A and D or C and D (p>0.05).

Age Group Comparison	Kidney	Weight (t, df, p)	Length (t, df, p)	Breadth (t, df, p)	Thickness (t, df, p)
A vs B	Left	t=3.604, df=1, p=.001	t=0.040, df=1, p=.001	t=0.040, df=1, p=.005	t=0.292, df=1, p=.10
	Right	t=95.871, df=1, p=.001	t=0.008, df=1, p=.001	t=0.008, df=1, p=.05	t=2.047, df=1, p=.10
A vs C	Left	t=105.355, df=1, p=.001	t=0.011, df=1, p=.050	t=0.423, df=1, p=.001	t=0.845, df=1, p=.10
	Right	t=94.128, df=48,	t=0.519,	t=0.387, df=1,	t=1.521, df=1,

		p=.001	df=1, p=.50	p=.001	p=.10
A vs D	Left	t=0.065, df=1, p=.50	t=1.318, df=1, p=.50	t=1.942, df=1, p=.05	t=6.991, df=1, p=.001
	Right	t=0.054, df=1, p=.50	t=0.404, df=1, p=.10	t=0.509, df=1, p=.001	t=7.361, df=1, p=.001
B vs C	Left	t=0.019, df=1, p=.50	t=0.006, df=1, p=.001	t=0.599, df=1, p=.05	t=0.219, df=1, p=.001
	Right	t=5.695, df=1, p=.50	t=0.298, df=1, p=.50	t=0.373, df=1, p=.05	t=5.505, df=1, p=.10
B vs D	Left	t=2.258, df=1, p=.001	t=0.496, df=1, p=.001	t=0.163, df=1, p=.001	t=0.258, df=1, p=.10
	Right	t=62.432, df=1, p=.001	t=0.075, df=1, p=.001	t=1.787, df=1, p=.001	t=2.295, df=1, p=.10
C vs D	Left	t=60.574, df=1, p=.001	t=0.392, df=1, p=.50	t=2.907, df=1, p=.05	t=0.998, df=1, p=.10
	Right	t=75.396, df=1, p=.001	t=0.067, df=1, p=.50	t=0.318, df=1, p=.05	t=1.048, df=1, p=.10

Table 3: Comparison of Kidney Measurements between Age Groups (Independent t-test)

There were also big differences in breadth between A and C (Left: t=0.423, p=0.001; Right: t=0.387, p=0.001), B and D (Right: t=1.787, p=0.001), and C and D (Left: t=2.907, p=0.05). There were very big variations in thickness between A and D (Left: t=6.991, p=0.001; Right: t=7.361, p=0.001), and B and C (Left: t=0.219, p=0.001). However, several other comparisons, such A and B, B and D, and C and D, did not reveal significant p-values (≥0.10). Overall, the 20–39 age group (Group B) had the highest glomerular number, size, and kidney dimensions. These differences were statistically significant when compared to both younger and older age groups, which suggests that the structure of the kidneys changes with age.

Discussion

The current study found that the right and left human kidneys have different shapes and sizes, especially in terms of cortical thickness, vascular distribution, and glomerular density. These results are in line with more general observations about anatomy and histology in both human

and animal models. For instance, Treuting et al. have written about how the shapes of organs, such as the kidneys, are different in humans than in rodents and mice. They stress how the position of organs and how they grow might affect these differences [10]. Our results confirm this idea by showing that there are constant disparities between the right and left kidneys. These differences may be due to their embryological origins and the mechanical limits set by nearby organs. Hermsen et al. used deep learning models to look at renal histology and found that the kidney has different structures in different areas, especially in the cortical zones [12]. The left kidney in our study had a thicker cortex and glomeruli that were more uniformly spread out. This is similar to what Hermsen found about cortical heterogeneity. This regularity makes it likely that these kinds of histological asymmetries are a normal part of the structure rather than anything strange.

Interestingly, Lawlor et al. used cellular extrusion bioprinting on kidney organoids and found that the structural organization was more consistent, which supports the idea that even lab-made tissues can show diverse patterns of differentiation in various areas [13]. The variations we saw between the right and left kidneys in our study were probably due to this kind of intrinsic developmental programming, not only functional adaptation. Bertog et al.'s investigation on renal denervation in pigs, on the other hand, only looked at symmetrical organ therapy and didn't report any differences in structure based on laterality. This may have been because the experimental model was controlled [8]. But the lack of side-specific histological examination makes it hard to compare the two studies. Stan looked at the anatomy of the liver in different species, and his findings on bilateral asymmetry show how important it is to compare paired organs among mammals in order to have a better picture of functional specialization [9].

Recent improvements in renal histotechnology and imaging have made it possible to map structures with great resolution. Fereidouni et al. used UV surface excitation microscopy to show that histology may be done quickly and without slides. This method can show small changes in microstructure, even those that may differ across the two sides of the kidney [19]. When used in clinical settings, these kinds of technologies could make it easier to find problems like kidney neoplasms and fibrosis, which may show up in an uneven way. Perdiki et al. wrote about examples of anastomosing hemangiomas that only affected one kidney, which shows how important laterality is in renal disease [11]. Also, Zhao et al.'s study of intact human organs at the cellular and molecular levels showed that there is a lot of variation within organs. This supports our result that the left and right kidneys may be different not

only in shape but also at the molecular and microenvironmental levels [14]. Abedini et al. used single-cell spatial profiling and discovered that different kidney areas had varied fibrotic signatures and microvascular patterns, which added to this heterogeneity [20].

Lastly, Bábíčková et al. found that renal illness progression, no matter what caused it, changes peritubular capillaries. These changes may look different in various kidneys because of differences in their basic anatomy [22]. These kinds of structural predispositions might help explain why some kidney diseases tend to affect one kidney more than the other in real life. In short, the study's findings of asymmetrical features are substantially confirmed by earlier research using different models and technology. These discrepancies have big effects on nephrological diagnoses, planning surgeries, and tactics for organ transplantation. More multi-omic and functional research are needed to fully understand the effects and extent of laterality on kidney structure and disease.

Conclusion

This study finds that there are big changes in the shape and structure of the right and left human kidneys, especially in the thickness of the cortex, the distribution of glomeruli, and the structure of the blood vessels. These differences, which are backed up by research in comparative anatomy and histology, show how important it is to think about renal laterality while making clinical diagnoses, planning surgeries, and interpreting pathology. The results show that region-specific anatomical data, especially in South Asia, is needed to improve the accuracy of diagnoses and the effectiveness of treatments. It is suggested that future studies combine molecular and imaging tools to look into the functional effects of these structural changes in both healthy and sick states.

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GROUP 2: Revising the work critically for important intellectual content

GROUP 3: Final approval of the version to be published

GROUP 4: Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

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GROUP 1: Analysis and Interpretation of data

GROUP 2: Revising the work critically for important intellectual content

GROUP 3: Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Dr. Mohammad Fokhruzzaman

GROUP 1: Interpretation of data

GROUP 2: Revising the work critically for important intellectual content

GROUP 3: Final approval of the version to be published

Rubaya Sultana

GROUP 1: Design of the work

GROUP 2: Revising the work critically for important intellectual content

GROUP 3: Final approval of the version to be published

Jannatul Taslima Meem

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GROUP 2: Revising the work critically for important intellectual content

GROUP 3: Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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GROUP 1: Interpretation of data

GROUP 2: Revising the work critically for important intellectual content

GROUP 3: Final approval of the version to be published

Dr.Shweta Halder

GROUP 1: Design of the work

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GROUP 2: Revising the work critically for important intellectual content

GROUP 3: Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.