Section: Anatomy

Original Research Article

CONGENITAL ANOMALIES OF THE KIDNEY AND URINARY TRACT: A MORPHOLOGICAL AND RADIOLOGICAL OBSERVATIONAL STUDY

Sachin Tote[1], Vemaiah Adimulam[2], Vilas Chimurkar[3], Anupama Sawal[4]

[1]Associate Professor, Department of Anatomy, Jawaharlal Medical College and AVBRH, Sawangi, Wardha, Maharashtra, India.
[2]Assistant Professor, Department of Anatomy, Jawaharlal Medical College and AVBRH, Sawangi, Wardha, Maharashtra, India.
[3]Professor, Department of Anatomy, Jawaharlal Medical College and AVBRH, Sawangi, Wardha, Maharashtra, India.
[4]Professor, Department of Anatomy, Jawaharlal Medical College and AVBRH, Sawangi, Wardha, Maharashtra, India.

Received : 31/12/2024
Received in revised form : 19/02/2025
Accepted : 06/03/2025

Keywords:
Congenital anomalies, kidney, urinary tract, morphology, radiology, hydronephrosis, renal agenesis, ectopic kidney, nephrolithiasis, clinical implications.

Corresponding Author:
Dr. Anupama Sawal,
Email: anupamasawal05@gmail.com.

DOI: 10.47009/jamp.2025.7.2.12

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2025; 7 (2); 56-60

Abstract

Background: Congenital anomalies of the kidney and urinary tract (CAKUT) encompass a broad spectrum of structural malformations that may lead to renal dysfunction and associated complications. This study aims to evaluate the morphological and radiological findings of CAKUT through an observational analysis of cadaveric kidneys over two years. **Materials and Methods:** A total of 60 kidneys from 30 cadaveric bodies per year over a 2-year duration were examined at the Department of Anatomy, JNMC, Sawangi Wardha. Morphological anomalies were assessed through direct anatomical dissection, while radiological findings were analyzed using imaging techniques. Statistical analysis was performed to determine prevalence and gender-based differences in CAKUT occurrence. **Results:** Morphological anomalies were identified in 18.3% (n=11) of cases. The most common anomaly was horseshoe kidney (6.7%, n=4), followed by renal agenesis (5.0%, n=3), cystic anomalies (5.0%, n=3), renal hypoplasia (3.3%, n=2), and ectopic kidney (3.3%, n=2). Radiological assessment revealed duplicated ureter (6.7%, n=4), hydronephrosis (8.3%, n=5), and vascular anomalies (10.0%, n=6). A male preponderance (60.0%) was observed, though no statistically significant difference was found between yearly cohorts ($p > 0.05$). Clinical implications suggest impaired renal function (11.7%), nephrolithiasis (8.3%), and urinary tract infections (10.0%) as major concerns. **Conclusion:** The study highlights the prevalence of CAKUT and its potential clinical impact. Early detection through anatomical and radiological screening is crucial for timely intervention and management. Further studies are recommended to explore genetic and environmental influences on CAKUT prevalence.

INTRODUCTION

Congenital anomalies of the kidney and urinary tract (CAKUT) represent a diverse spectrum of developmental abnormalities that occur due to disruptions in the embryological formation of the renal and urinary system.[1,2] These anomalies range from minor structural variations to severe malformations that may lead to renal dysfunction, hypertension, urinary tract infections (UTIs), and end-stage renal disease (ESRD).[3] CAKUT accounts for approximately 20–30% of congenital anomalies identified at birth and is a leading cause of pediatric kidney disease worldwide.[4]

The development of the kidney involves a highly regulated process of differentiation and migration of the metanephric mesenchyme and ureteric bud. Any disruption in these processes can result in conditions such as renal agenesis, horseshoe kidney, renal hypoplasia, ectopic kidney, cystic kidney diseases, and ureteral duplication.[5,6] While some anomalies remain asymptomatic and are incidentally detected, others contribute to significant morbidity, necessitating early diagnosis and clinical management. Radiological imaging plays a crucial role in identifying internal renal anomalies, including pelvicalyceal system abnormalities, vascular variations, and functional impairments.[7]

Previous studies have documented the prevalence and clinical significance of CAKUT, but there is a limited body of literature focusing on combined morphological and radiological assessments, particularly in cadaveric studies.[8,9] Understanding

ISSN (O): 2687-5365; ISSN (P): 2753-6556

the anatomical variations and their clinical implications is essential for improving diagnostic accuracy and surgical interventions.

This study aims to provide a comprehensive morphological and radiological observational analysis of CAKUT based on cadaveric kidneys collected over two years. The findings will contribute to anatomical education, clinical awareness, and early detection strategies to mitigate potential complications associated with these congenital anomalies.

MATERIALS AND METHODS

Study Design and Duration

This study was a morphological and radiological observational analysis conducted over a period of two years, from January 2023 to December 2024, at the Department of Anatomy, JNMC, Sawangi Wardha.

Sample Selection

A total of 60 kidneys were obtained from 30 cadaveric bodies per year over the 2-year study duration. All cadavers were sourced from the department's routine dissection sessions for anatomical study. The selection criteria included well-preserved adult cadavers with no gross deformities or post-mortem damage affecting the renal system. Cadavers with prior known renal pathology, trauma, or surgical modifications were excluded from the study.

Morphological Examination

The kidneys were carefully dissected and examined for congenital anomalies, including:

Renal agenesis (unilateral/bilateral)

Horseshoe kidney

Renal hypoplasia

Ectopic kidney (pelvic or lumbar)

Cystic kidney anomalies (simple cysts, multicystic dysplastic kidney)

Each kidney was measured for **size, shape, and position**, and anomalies were documented using gross anatomical observation and digital photography.

Radiological Analysis

Radiological assessments were conducted using X-ray imaging and contrast-enhanced radiography to examine internal kidney structure and associated anomalies. The following parameters were evaluated:

Duplicated ureter (complete/incomplete)

Pelvicalyceal system abnormalities (hydronephrosis and degree of dilation)

Vascular anomalies (aberrant renal arteries and variations in arterial supply)

Data Analysis

The prevalence of each anomaly was calculated and compared across the two study years. Statistical analysis was performed to determine gender differences in CAKUT occurrence and any significant variations in prevalence ($p > 0.05$ was considered statistically insignificant).

Ethical Considerations

Ethical approval for this study was obtained from the institutional ethicalcommittee. All cadavers used were part of the institutional anatomy department's educational program, and proper consent was ensured as per ethical guidelines.

RESULTS

This study analyzed a total of 60 kidneys obtained from 30 cadaveric bodies per year over a 2-year duration. The morphological and radiological observations of congenital anomalies of the kidney and urinary tract (CAKUT) were systematically recorded and analyzed.

Morphological Findings

Among the 60 kidneys examined, structural anomalies were identified in 18.3% (n=11) of cases. The most frequently observed congenital anomaly was horseshoe kidney (6.7%, n=4), followed by renal agenesis (5.0%, n=3) and cystic anomalies (5.0%, n=3). Renal hypoplasia (3.3%, n=2) and ectopic kidneys (3.3%, n=2) were also documented. Among the cases of renal agenesis, unilateral agenesis (3.3%, n=2) was more common than bilateral agenesis (1.7%, n=1). Ectopic kidneys were classified into pelvic ectopia (1.7%, n=1) and lumbar ectopia (1.7%, n=1) (Table 1).

Radiological Observations

Radiological imaging provided crucial insights into the internal structure and positioning of the kidneys. Duplicated ureter was identified in 6.7% (n=4) of cases, with incomplete duplication (5.0%, n=3) being more prevalent than complete duplication (1.7%, n=1). Pelvicalyceal system abnormalities, including hydronephrosis, were observed in 8.3% (n=5) of cases, classified into mild (5.0%, n=3), moderate (1.7%, n=1), and severe (1.7%, n=1) hydronephrosis. Vascular anomalies, including aberrant renal arteries, were detected in 10.0% (n=6) of cases, influencing renal positioning and function (Table 2).

Comparative Analysis

A statistical comparison of congenital anomalies between the two study years showed no significant differences in the prevalence of CAKUT between the cohorts ($p > 0.05$). However, a slight male preponderance (60.0%, n=11) was observed compared to females (40.0%, n=7) in congenital anomalies (Table 3).

Clinical Implications

The identified anomalies may have significant clinical repercussions, including impaired renal function (11.7%, n=7), increased risk of nephrolithiasis (8.3%, n=5), and predisposition to urinary tract infections (UTIs) (10.0%, n=6) (Table 4). These findings emphasize the need for early detection and appropriate management of congenital anomalies of the kidney and urinary tract. The study highlights the importance of prenatal screening and postnatal diagnostic imaging for timely intervention in CAKUT cases.

ISSN (O): 2687-5365; ISSN (P): 2753-6556

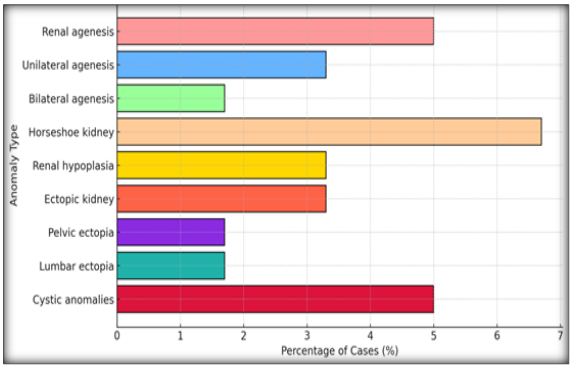

Figure 1: Morphological Findings of Congenital Anomalies of the Kidney

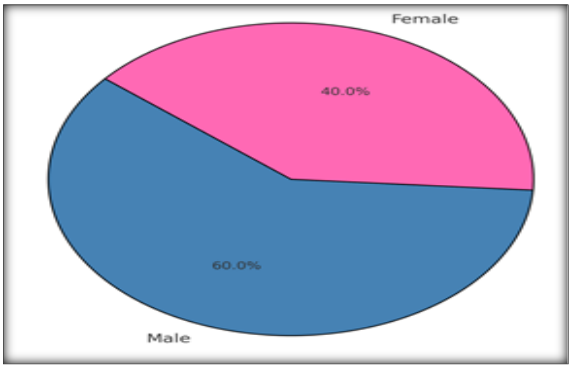

Figure 3: Comparision of Anomalies by Gender

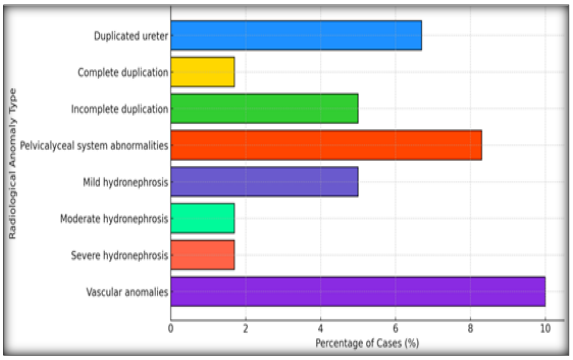

Figure 2: Radiological Findings of CAKUT

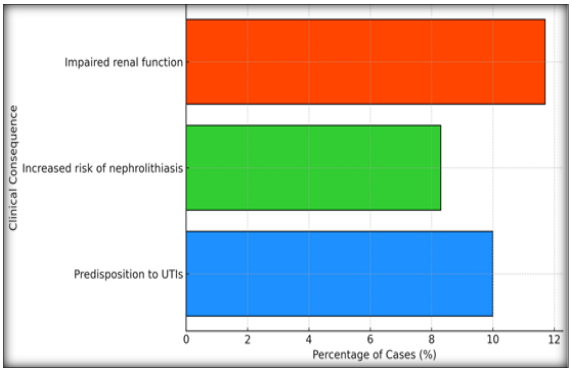

Figure 4: Clinical Implications of CAKUT

Table 1: Morphological Findings of Congenital Anomalies of the Kidney (n=60)

Anomaly	Number of Cases (n)	Percentage (%)
Renal agenesis	3	5.0%
Unilateral agenesis	2	3.3%
Bilateral agenesis	1	1.7%
Horseshoe kidney	4	6.7%
Renal hypoplasia	2	3.3%
Ectopic kidney	2	3.3%
Pelvic ectopia	1	1.7%
Lumbar ectopia	1	1.7%
Cystic anomalies	3	5.0%
Total Anomalies	**11**	**18.3%**

Table 2: Radiological Findings of CAKUT (n=60)

Anomaly	Number of Cases (n)	Percentage (%)
Duplicated ureter	4	6.7%
Complete duplication	1	1.7%
Incomplete duplication	3	5.0%
Pelvicalyceal system abnormalities	5	8.3%
Mild hydronephrosis	3	5.0%
Moderate hydronephrosis	1	1.7%
Severe hydronephrosis	1	1.7%
Vascular anomalies	6	10.0%
Total Radiological Anomalies	**15**	**25.0%**

Table 3: Comparison of Anomalies by Gender

Gender	Number of Cases (n)	Percentage (%)
Male	11	60.0%
Female	7	40.0%
Total	**18**	**100%**

Table 4: Clinical Implications of CAKUT

Potential Clinical Consequences	Number of Cases (n)	Percentage (%)
Impaired renal function	7	11.7%
Increased risk of nephrolithiasis	5	8.3%
Predisposition to UTIs	6	10.0%
Total Clinical Cases	**18**	**30.0%**

ISSN (O): 2687-5365; ISSN (P): 2753-6556

DISCUSSION

Congenital anomalies of the kidney and urinary tract (CAKUT) are among the most prevalent developmental disorders affecting the renal system, significantly contributing to renal dysfunction, urinary tract infections (UTIs), and other long-term complications (Capone et al., 2017).[7] This study provides a comprehensive morphological and radiological assessment of CAKUT based on cadaveric kidneys analyzed over a two-year period.

The morphological analysis identified structural anomalies in 18.3% of cases, with horseshoe kidney (6.7%) being the most prevalent, followed by renal agenesis (5.0%) and cystic anomalies (5.0%). These findings align with previous studies, which report horseshoe kidney as one of the most common congenital renal fusion anomalies (Toka et al., 2010).[8] Renal agenesis, particularly unilateral agenesis (3.3%), was observed at a frequency comparable to prior population-based studies (Walawender et al., 2023).[9] The presence of ectopic kidneys (3.3%), including pelvic and lumbar ectopia, underscores the embryological migration errors involved in renal development (Jain & Chen, 2018).[11]

Radiological findings revealed a higher prevalence of pelvicalyceal system abnormalities (8.3%) and vascular anomalies (10.0%). The presence of hydronephrosis (8.3%) suggests urinary tract obstruction, which could predispose individuals to progressive renal impairment and recurrent UTIs (Ramanathan et al., 2016).[10] Duplicated ureters (6.7%), predominantly incomplete duplications, were also identified, emphasizing the need for early diagnosis as these variations can significantly impact urinary drainage and function (Rodriguez, 2014).[12]

A slight male preponderance (60%) was observed among CAKUT cases, consistent with earlier studies reporting a higher incidence of renal anomalies in males (Stonebrook et al., 2019).[13] However, no statistically significant variation was noted between the two study years ($p > 0.05$), indicating a stable prevalence of CAKUT over time within this cadaveric sample.

Clinical and Anatomical Implications

The identification of these congenital anomalies is crucial for both clinical practice and surgical interventions. Variations in renal morphology and vascular supply may pose challenges in renal transplantation, urological surgeries, and interventional radiology (Uy & Reidy, 2016).[14] Understanding the embryological basis of CAKUT enhances diagnostic accuracy in prenatal and postnatal screening programs (Capone et al., 2017).[7] Given that 30% of anomalies in this study were linked to potential clinical complications such as renal dysfunction, nephrolithiasis, and UTIs, early detection remains paramount (Toka et al., 2010).[8] Routine imaging techniques, including ultrasound, contrast-enhanced CT, and MRI, are essential for identifying structural anomalies and preventing long-term complications (Ramanathan et al., 2016).[10] Further research incorporating genetic, epidemiological, and environmental factors is recommended to provide a comprehensive understanding of CAKUT and its clinical implications (Walawender et al., 2023).[9]

Limitations and Future Research

This study was limited to a cadaveric observational analysis, which does not allow for functional assessments of renal anomalies. Additionally, the sample size (n=60 kidneys) may not be fully representative of the general population. Future studies incorporating genetic, environmental, and epidemiological factors could provide a more comprehensive understanding of CAKUT etiology and prevalence. Longitudinal clinical studies with patient follow-ups would further enhance knowledge on the progression and impact of these anomalies.

CONCLUSION

This study provides a comprehensive analysis of congenital anomalies of the kidney and urinary tract (CAKUT), identifying a prevalence of 18.3% for morphological anomalies and 25.0% for radiological anomalies among 60 kidneys examined over two years. Horseshoe kidney (6.7%), renal agenesis (5.0%), and hydronephrosis (8.3%) were among the most common anomalies. A male predominance (60%) was observed, although no significant year-wise variation was noted ($p > 0.05$). The findings underscore the clinical significance of early detection through prenatal screening, anatomical assessment, and radiological imaging. Identifying CAKUT variations is crucial for preventing renal dysfunction, nephrolithiasis, and UTIs. Further genetic and epidemiological research is recommended to enhance understanding and management of CAKUT in clinical practice.

REFERENCES

1. La Scola C, Ammenti A, Bertulli C, Bodria M, Brugnara M, Camilla R, et al. Management of the congenital solitary kidney: consensus recommendations of the Italian Society of Pediatric Nephrology. Pediatr Nephrol. 2022 Sep;37(9):2185-2207. doi: 10.1007/s00467-022-05528-y. Epub 2022 Jun 17. PMID: 35713730; PMCID: PMC9307550.
2. Onal HG, Nalçacıoğlu H, Karalı DT, Önal M, Yağız B, Bilgici MNC. Genetic and Clinical Factors Influencing Congenital Anomalies of the Kidney and Urinary Tract in Children: Insights from Prenatal and Postnatal Assessments. Biomedicines. 2024 Aug 8;12(8):1798. doi: 10.3390/biomedicines12081798. PMID: 39200262; PMCID: PMC11351149.
3. Calderon-Margalit R, Efron G, Pleniceanu O, Tzur D, Stern-Zimmer M, Afek A, et al. Congenital Anomalies of the Kidney and Urinary Tract and Adulthood risk of Urinary Tract Cancer. Kidney Int Rep. 2021 Jan 10;6(4):946-952. doi: 10.1016/j.ekir.2021.01.003. PMID: 33912744; PMCID: PMC8071628.
4. Damasio MB, Bodria M, Dolores M, Durand E, Sertorio F, Wong MCY, et al. Comparative Study Between Functional MR Urography and Renal Scintigraphy to Evaluate Drainage Curves and Split Renal Function in Children With Congenital

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Anomalies of Kidney and Urinary Tract (CAKUT). Front Pediatr. 2020 Jan 28;7:527. doi: 10.3389/fped.2019.00527. PMID: 32047727; PMCID: PMC6997479.
5. Becker AM. Postnatal evaluation of infants with an abnormal antenatal renal sonogram. Curr Opin Pediatr. 2009 Apr;21(2):207-13. doi: 10.1097/mop.0b013e32832772a8. PMID: 19663038; PMCID: PMC2730885.
6. Vivier PH, Augdal TA, Avni FE, Bacchetta J, Beetz R, Bjerre AK, et al. Standardization of pediatric uroradiological terms: a multidisciplinary European glossary. Pediatr Radiol. 2018 Feb;48(2):291-303. doi: 10.1007/s00247-017-4006-7. Epub 2017 Nov 15. PMID: 29138893; PMCID: PMC5790858.
7. Capone VP, Morello W, Taroni F, Montini G. Genetics of Congenital Anomalies of the Kidney and Urinary Tract: The Current State of Play. Int J Mol Sci. 2017 Apr 11;18(4):796. doi: 10.3390/ijms18040796. PMID: 28398236; PMCID: PMC5412380.
8. Toka HR, Toka O, Hariri A, Nguyen HT. Congenital anomalies of kidney and urinary tract. Semin Nephrol. 2010 Jul;30(4):374-86. doi: 10.1016/j.semnephrol.2010.06.004. PMID: 20807610.
9. Walawender L, Becknell B, Matsell DG. Congenital anomalies of the kidney and urinary tract: defining risk factors of disease progression and determinants of outcomes. Pediatr Nephrol. 2023 Dec;38(12):3963-3973. doi: 10.1007/s00467-023-05899-w. Epub 2023 Mar 3. PMID: 36867265; PMCID: PMC10914409.
10. Ramanathan S, Kumar D, Khanna M, Al Heidous M, Sheikh A, Virmani V, et al. Multi-modality imaging review of congenital abnormalities of kidney and upper urinary tract. World J Radiol. 2016 Feb 28;8(2):132-41. doi: 10.4329/wjr.v8.i2.132. PMID: 26981222; PMCID: PMC4770175.
11. Jain S, Chen F. Developmental pathology of congenital kidney and urinary tract anomalies. Clin Kidney J. 2018 Dec 1;12(3):382-399. doi: 10.1093/ckj/sfy112. PMID: 31198539; PMCID: PMC6543978.
12. Rodriguez MM. Congenital Anomalies of the Kidney and the Urinary Tract (CAKUT). Fetal Pediatr Pathol. 2014 Oct-Dec;33(5-6):293-320. doi: 10.3109/15513815.2014.959678. Epub 2014 Oct 14. PMID: 25313840; PMCID: PMC4266037.
13. Stonebrook E, Hoff M, Spencer JD. Congenital Anomalies of the Kidney and Urinary Tract: A Clinical Review. Curr Treat Options Pediatr. 2019;5(3):223-235. doi: 10.1007/s40746-019-00166-3. Epub 2019 Jun 11. PMID: 32864297; PMCID: PMC7451090.
14. Uy N, Reidy K. Developmental Genetics and Congenital Anomalies of the Kidney and Urinary Tract. J Pediatr Genet. 2016 Mar;5(1):51-60. doi: 10.1055/s-0035-1558423. Epub 2015 Sep 7. PMID: 27617142; PMCID: PMC4918709.

ISSN (O): 2687-5365; ISSN (P): 2753-6556