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Original Article

Anatomy Section

Anatomical and Developmental Abnormalities of Kidney and Ureter: A Cadaveric Study from Karnataka, India

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ABSTRACT

Introduction: Cadaveric studies of kidneys and ureters serve as the foundational bedrock for understanding human urological anatomy, providing irreplaceable insights into structural variations that directly impact clinical practice across surgery, radiology and medical education. These meticulous dissections reveal a landscape far more complex and variable than textbook illustrations suggest, with profound implications for patient safety and procedural success.

Aim: To evaluate the prevalence of anatomical and developmental abnormalities of kidneys and ureters in human cadavers.

Materials and Methods: The present retrospective study was conducted during routine dissections of 34 cadavers over a period of five years from August 2019 to July 2024 at Department of Anatomy, The Oxford Medical College, Hospital and Research Centre in Bangalore, Karnataka, India. The study was planned and executed from December 2024 to November 2025. All specimens included in the present study were adult cadavers of which 20 were males and 14 were females. Photographs of the anomalous and developmental abnormalities were taken for proper documentation. Descriptive statistics were used to statistically analyse the data.

Results: Out of 34 cadavers, 1 (2.94%) cadaver showed Hydronephrosis (HN) in left kidney, 1 (2.94%) cadaver showed partial duplication of right ureter, 5 (14.7%) cadavers showed lobulated kidneys and 6 (17.6%) cadavers showed cystic kidneys.

Conclusion: Cystic kidney was the most common anomaly observed in the present study. Knowledge of anatomical variations is essential for urological, transplant and vascular surgeries. The identification of duplicate ureters and anomalies during cadaveric dissection provides surgeons with critical preoperative planning information.

Keywords: Cystic kidney, Duplication of ureter, Hydronephrosis, Lobulated kidney

INTRODUCTION

With the advancement of interventional radiological procedures, vascular operations, urological procedures and renal transplantations, findings of renal tract anomalies are more common [1]. The urinary system includes a pair of kidneys and their ureters, urinary bladder and urethra. The kidneys are a pair of bean-shaped organs situated in the posterior abdominal wall between the 12th thoracic and third lumbar vertebrae. Each kidney is around the size of a fist, measuring approximately 10-12 cm in length. Urine is transported from the kidneys to the bladder by the ureters, which are two muscular tubes that contract peristaltically [2].

Ureteral duplication may be incomplete or complete. Incomplete duplication is also known as a bifid collecting system. With an incidence of 0.7 to 4%, unilateral duplication of the ureter is a frequent congenital renal anomaly [3]. At autopsies, the incidence is 0.8% [4]. Renal tract duplication is more common in women [3]. Patients are typically asymptomatic. On the other hand, they could exhibit a range of symptoms in their clinical presentation, including ureterocele, vesicoureteral reflux, urinary stones, recurrent urinary tract infections and obstructive uropathy [5].

Multiple lobulations of the kidney are witnessed throughout the foetal life [6]. Most of them disappear during the first year of birth but differing degrees of lobulations may persist in adult life. It is caused due to incomplete fusion of developing renal lobules [7]. Cystic diseases of kidney are heterogenous, comprising of hereditary, developmental and acquired disorders. They account for 6-8% of patients on dialysis. Adult Polycystic Kidney Disease (ADPKD) is a major cause of chronic kidney disease. ADPKD is an autosomal dominant disease with high penetrance and occurs in 1 out of 400 to 1000 persons and accounts for 5 to 10% of chronic renal failure [8].

The dilatation of the kidney's renal collecting system caused by an obstruction of urine outflow in any part of the urinary tract is known as HN. It can manifest alone or in addition with ureter dilatation in a condition known as hydroureteronephrosis. At any age, HN can manifest as either unilateral or bilateral, acute or chronic [9]. Although renal and ureteric anomalies have been described in radiological and clinical studies, detailed cadaveric investigations evaluating the combined morphology of kidney and ureter are limited. Furthermore, population-specific data on the incidence and morphometry of these anomalies remain scarce. Thus, the present study aims to provide a comprehensive anatomical analysis of kidney and ureter variations such as double ureter, cystic kidney, lobulated kidney and HN in the cadavers and their clinical significance.

MATERIALS AND METHODS

The present retrospective study was performed over a period of five years from August 2019 to July 2024 and executed from December 2024 to November 2025 on well preserved human cadavers in the Anatomy Department of the Oxford Medical College, Hospital and Research Centre, Bengaluru, Karnataka, India. This study was approved by the Institutional ethics committee (reference no. IEC/DHR/TOMCH&RC/125/2025-26).

Inclusion and Exclusion criteria: All the cadavers used for dissection of undergraduate teaching, over a period of five years from August 2019 to July 2024 were included in the present study. Damaged kidneys due to improper handling during dissection were excluded.

Study Procedure

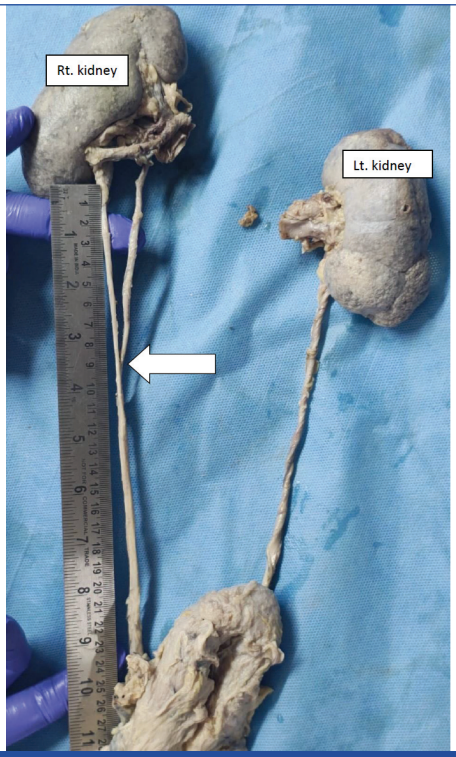
All specimens over a period of five years from August 2019 to July 2024 at Department of Anatomy were taken in the present study. Study included 34 adult cadavers of which 20 were males and 14 were females. All the specimens were properly dissected and observed on both the right and the left sides to inspect the presence of any anatomical and developmental abnormalities in the kidney and ureter such as bifid ureter, HN, cystic kidney and lobulated kidney. The dissection method used was based on the Cunningham's dissection manual [10].

STATISTICAL ANALYSIS

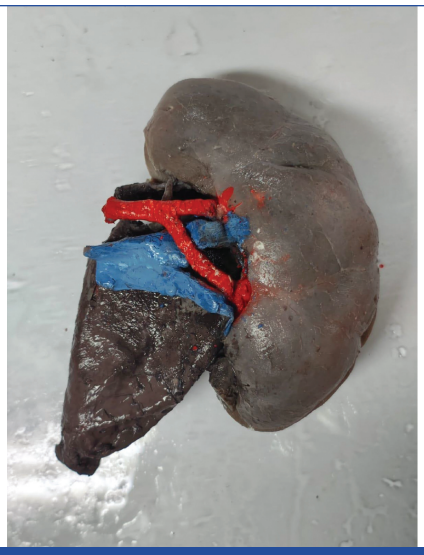
The collected data was entered into the Microsoft excel sheet and analysed. The data was presented descriptively.

RESULTS

Out of the 34 cadavers studied, 20 were of males and 14 were of females. Among the 34 cadavers studied, 2.94% (1 cadaver) had partial double right ureter [Table/Fig-1], 2.94% had (1 cadaver) HN [Table/Fig-2], 14.7% (5 cadavers) had lobulated kidneys [Table/Fig-3] and 17.6% (6 cadavers) had cystic kidneys [Table/Fig-4,5].



[Table/Fig-1]: Partial duplication of ureter.



[Table/Fig-2]: Hydronephrosis (HN).

[Table/Fig-3]: Lobulated kidney.

[Table/Fig-4]: Cystic kidney.

Anomalies/abnormalities	Total number of cadavers studied (20 males, 14 females)	Prevalence (%) - unilateral
Double ureters (partial)	34	2.94% (1 male cadaver)
Hydronephrosis (HN) of kidneys	34	2.94% (1 male cadaver)
Lobulated kidney	34	14.7% (2 male and 3 female cadaver)
Cystic kidney	34	17.6% (3 male and 3 female cadaver)

[Table/Fig-5]: Anatomical and developmental abnormalities of kidneys and ureters.

DISCUSSION

The anatomical and developmental abnormalities of kidneys and ureters observed in this study included partial duplication of ureter, HN, lobulated kidney and cystic kidney. In the present study, the authors found the partial duplication of right ureter in one male cadaver. In the fifth week of foetal development inside the womb, the ureter starts to form. The mesonephros and its duct are the initial type of kidneys, following the pronephros. Later, the metanephros develops. The ureteric bud comes out from the mesonephric duct as a small pouch and then grows into the nephrogenic blastema. From this bud, branches form that create the collecting system of the kidney. If the ureteric bud divides before fully reaching the blastema, it can lead to a condition called unilateral ureter duplication [11]. For the ureter and the collecting system to develop fully, the ureteric bud

and the blastema must work together. Both the ureteric bud and the nephrogenic mesenchyme express the gene PAX2. A change in this gene can cause the ureter to split into two [12].

Research suggests that problems with the development of the gonads might be linked to issues in the upper part of the urinary tract [13]. Two important factors that help the ureteric bud grow and extend are Bone Morphogenetic Factor 4 (BMP-4) and a factor made by glial cells. BMP-4 is essential for the normal development of the kidney structures [14]. In terms of embryology, a single ureteric bud may split before it joins the mesenchyme, leading to the formation of a double kidney and a split ureter. If two buds form near each other on the mesonephric duct, this results in full duplication of the ureters [15]. The cause of partial duplication is not clear, but it can happen if the ureteric bud splits before it connects to the blastema. A common but temporary condition called uretero-ureteral reflux, also known as seesaw, saddle, or yo-yo reflux, is due to partial ureter duplication. Sometimes, a double system is found by chance during surgery or an abdominal check-up [16]. Routine tests called excretory urograms show that about 3% of cases have duplicated ureters [17]. Although this is sometimes diagnosed in adulthood, it is usually found in childhood or during pregnancy. Various imaging tests like nuclear medicine, computed tomography, excretory urograms and ultrasound are used for diagnosis. In adults, Computed Tomography (CT) scans often show HN, which is more common in the upper part of the kidney [18]. Tang M et al., have described cases where there are two duplicate collecting systems with an ectopic ureteral opening on the right-side [19].

In the present study, HN was observed in one cadaver. The HN is when the urinary collecting system of the kidney becomes swollen. This happens when there is a blockage preventing urine from moving from the kidney to the bladder. The blockage can be anywhere in the urinary tract, such as in the ureters, bladder, or urethra. This condition can range from mild swelling to severe enlargement that might harm the kidney. Common causes include kidney stones, pregnancy, Pelviureteric Junction (PUJ) stenosis or bladder outlet obstruction [20]. The blockage increases pressure in the urinary system, leading to the swelling of the renal pelvis and calyces. Hansen KL et al., found that stones were the most common reason for HN in adults [21]. In a study by Riddell J et al., bedside ultrasound had a sensitivity of 72% to 83% in detecting unilateral HN [22]. Another study by Moş C et al., found that transabdominal ultrasound detected HN in 88.94% of cases and identified ureteral stones in around 73% of patients [23]. Sternberg KM et al., reported that ultrasound findings for HN had a positive predictive value of 77% and a negative predictive value of 71% for diagnosing ureteral stones [24].

In the present research, the authors found five lobulated kidneys (2 male and 3 female cadavers). A lobulated kidney occurs when foetal lobulation remains into adulthood. Normally, foetal kidneys form lobes that disappear by the end of the foetal period. This condition is due to incomplete merging of the developing kidney lobules. It is usually found by chance and has no clinical significance. However, during imaging, it is important to differentiate it from scarring, which can be caused by reflux or chronic infection. On CT or ultrasound, lobulation appears as smooth indentations between the pyramids of the kidney, unlike scars which lie over the pyramids. A lobulated kidney shows smooth, regular indentations in the kidney shape without thinning of the kidney tissue or issues with the underlying calyces. Often, this is a normal variation but needs to be distinguished from kidney scarring, kidney infarcts and tumours. It may look like a false tumour [25].

In the present study the authors observed six cystic kidneys (3 male and 3 female cadavers). Polycystic kidney disease is a genetic condition where many cysts grow in the kidneys. These cysts can make the kidneys larger and replace much of the normal structure, leading to reduced kidney function and kidney failure [26]. Autosomal Dominant Polycystic Kidney Disease (ADPKD) is the most common genetic kidney disorder, predominantly caused by pathogenic variants in the PKD1 and PKD2 genes. ADPKD affects up to 12 million people worldwide, with an estimated annual incidence of 2.5 cases per 100,000 individuals [27]. The characteristics of similar studies are presented in [Table/Fig-6] [5,28-37].

S. No.	Author's name and year	Place of study	Sample size	Objectives	Parameters assessed	Conclusion
1	Chakravarthi KK and Reghunadhan D, 2024 [28]	Malaysia	50	To evaluate the prevalence of anatomical and developmental variations of the renal pelvis and ureter,	Double ureters, Hydronephrosis (HN)	Prevalence of 10% for double ureters and 8% for Hydronephrosis (HN)
2	Shambharkar SB et al., 2018 [29]	Maharashtra, India	50	To study the anatomy of variations of kidney and ureter.	Bifid pelvis, cystic kidney, lobulated kidney	Prevalence of 07.07% for lobulated kidneys, 05.05% for polycystic kidneys, 02.02% for bifid pelvis were seen.
3	Choudhary U et al., 2017 [30]	Uttar Pradesh, India	32	To study of congenital anomalies of kidney and urinary tract.	Bifid ureter, Lobulated kidney	Prevalence of 9.4% for lobulated kidneys and, 6.25% for bifid ureter were seen.
4	Saha A 2024 [31]	Delhi, India	40	To observe the anatomy of renal pelvis and to study the branching pattern of ureter	Double ureter	Prevalence of 2.5% for double ureter was observed.
5	John SP et al., 2024 [32]	Mumbai, India	50	To study any anomalies of ureter in routine anatomical dissection	Bifid ureter	Prevalence of 1% for double ureter was observed.
6	Roy M et al., 2017 [33]	Maharashtra, India	156	To study the major anatomical variations of the ureter in routine dissection method	Double ureter	Prevalence of 0.64% for double ureter was observed
7	Armugam S et al., 2020 [5]	Guntur, India	50	To determine the prevalence of double ureters in a South Indian population	Double ureter	Prevalence of 6% for double ureter was observed
8	Kasat PA et al., 2018 [34]	Maharashtra, India	90	To study the morphological characteristics and variations of urinary system in the adult human cadavers	Lobulated kidney, Ectopic kidney, Hypoplastic kidney, Double ureter	Prevalence of 10% for lobulated kidneys, 3.3% for hypoplastic kidney, 1.1% for ectopic kidney and, 2.2% for bifid ureter were seen
9	Shambharkar SB et al., 2020 [35]	Maharashtra, India	50	To assess the normal parameters of kidney from the cadavers	Polycystic kidney	Prevalence of 12.3% for polycystic kidney was seen

10	Reddy PR, 2017 [36]	Telangana, India	50	To observe the different malformations in human kidneys among the adults human cadavers.	Lobulated kidney, Horseshoe kidney	Prevalence of 2% for lobulated and 1% for horseshoe kidney was observed.
11	Anturlikar SV et al., 2024 [37]	Maharashtra, India	24	To study the prevalence and characteristics of kidney and ureter anomalies	Horseshoe kidney, Double ureter, Polycystic kidney, Lobulated kidney	24% exhibited renal and ureteric anomalies, with 18% showcasing kidney anomalies and 10% displaying double ureter
12	Present study	Karnataka, India	34	To study the anatomical and developmental abnormalities of kidney and ureters	Double ureter, lobulated kidney, cystic kidney, Hydronephrosis (HN),	Prevalence of 2.94% for Hydronephrosis (HN), 2.94% for double ureter, 14.7% for lobulated kidneys and 17.6% for cystic kidneys were observed.

[Table/Fig-6]: Characteristics of similar research [5,28-37].

Limitation(s)

The availability of cadaveric specimens was limited by donation rates, ethical approval processes and institutional resources. This resulted in relatively small sample size which may lack statistical power to detect subtle anatomical variations or rare anomalies.

CONCLUSION(S)

The presence of partial ureter duplication, HN, lobulated kidney and cystic kidney, as observed in this study is of significant anatomical, developmental and clinical importance. Cadaveric studies serve as fundamental educational resources and research foundations for advancing anatomical knowledge and clinical practice. The future research recommendations are to correlate cadaveric findings with pre-mortem imaging (CT, Magnetic Resonance Imaging, ultrasound) to validate diagnostic accuracy.

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