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ORIGINAL ARTICLE

Role of multidetector computed tomography (MDCT) in evaluation of congenital renal anomalies.

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ABSTRACT… Objective: To evaluate the role of Multidetector Computed Tomography (MDCT) in the detailed assessment, characterization, and classification of congenital renal anomalies along with associated complications. **Study Design:** Cross-sectional Descriptive study. **Setting:** Department of Radiology in the Institute of Urology and Transplantation (IUTR), Rawalpindi. **Period:** September 2023 to February 2024. **Methods:** A cohort of 38 patients aged 8 to 77 years was examined to investigate a spectrum of renal abnormalities. The diagnostic protocol comprised a comprehensive quad-phase examination using a state-of-the-art multi-detector-row CT scanner. The acquired images underwent meticulous evaluation by two experienced radiologists. **Results:** The mean age of the participants was 41.1 years. Among the 38 suspected cases, 24 exhibited normal kidney anatomy, while congenital renal anomalies were identified in 14 patients. Migration and fusion anomalies were observed in 5 patients, including 2 with crossed fused ectopia and 3 with horseshoe kidneys. Ectopic pelvic kidneys were diagnosed in 3 patients. Additionally, 2 patients presented with a duplex collecting system, one accompanied by a bifid ureter. Unilateral renal agenesis was found in 3 patients, with one female patient having a coexisting Mullerian duct anomaly. **Conclusion:** Multidetector CT (MDCT) emerges as a crucial diagnostic tool for congenital renal anomalies, offering insights into fusion, shape, and position abnormalities.

Key words: Congenital Renal Anomalies, Kidneys, Multidetector Computed Tomography, Urinary Tract.

INTRODUCTION

Congenital renal anomalies constitute a heterogeneous array of structural irregularities effecting the kidneys and urinary tract, emerging during the intricate phases of fetal development.[1] During fetal life, kidney development involves three main stages: pronephros, mesonephros and metanephros (definitive kidney).[2] The ureteric bud branches forming collecting ducts, renal pelvis, calyces, and ureters. Nephrons differentiate, and kidneys ascend in position. Maturation continues postnatally. Disruptions or arrest in these processes can lead to congenital renal anomalies.[3]

Inherited mutations and chromosomal abnormalities play a genetic role, while maternal drug exposure, illnesses, and teratogenic agents are additional factors that may contribute as causative elements in these disorders.[4] These anomalies rank among the most common major birth defects, accounting for approximately 10-20% of all congenital abnormalities.[5] Prenatal imaging is valuable for detecting these disorders, yet postnatal imaging, occasionally in adulthood, becomes necessary to delineate the abnormality and assess any associated complications or conditions.[6]

MDCT is crucial for identifying renal disorders[7], offering high-resolution images for detailed visualization of kidney structures, contrast-enhanced imaging for vascular assessment[8], and precise characterization of masses if present. It plays a key role in detecting congenital anomalies[9], assessing urolithiasis, evaluating vascular anatomy[10] and guiding interventions.

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MDCT's versatility makes it essential for both diagnosis and follow-up in renal care.[11]

METHODS

This cross-sectional study took place at the Department of Radiology in the Institute of Urology and Transplantation (IUTR), Rawalpindi from September 1, 2023, to January 31, 2024. Ethical approval for this study was obtained under reference number IUTR/MS/846/2024. The inclusion criteria involved patients examined by urologists, advised CECT KUB to detect structural renal abnormalities, based on symptoms (abdominal pain (75 %), fever (21 %), weight loss (18 %), hematuria (16 %), positive family history of renal abnormalities (13 %). Exclusion criteria encompassed patients with deranged RFTs, pregnancy, ESRD patients on hemodialysis or those declining imaging.

Written informed consent was obtained from enrolled patients, with prior approval from the hospital's ethical committee. Patient information was collected using a structured form, and all participants underwent Quad phase examination including non-contrast, CT Angiography, nephrogenic and delayed phase of imaging. The prerequisites included an optimally filled urinary bladder. Non-contrast imaging was conducted spanning from the apex of the kidneys to the bladder, aiming to identify the presence of calculi, lesions containing fat, parenchymal calcifications, and to establish a baseline scan for assessing the shape, location of the kidneys, and potential associated anomalies. Subsequently, intravenous administration of contrast media was carried out, tailored to the patient's weight and age.

CT angiography of the renal vessels was performed using bolus tracking. Following a delay of 90 to 100 seconds, abdominal and pelvic scanning was undertaken during the nephrogenic phase. The ultimate acquisition occurred during the excretory phase, with a delay of 3 to 5 minutes. This phase allowed for the observation of opacification and distension of the collecting systems, ureter, and bladder. Scanning was carried out using a 160-slice multi-detector row CT scanner (Aquilion Prime SP; Cannon Medical Systems, Japan) using the following parameters: tube voltage – 120 kv; tube current – 40 mAs; slice thickness – 0.5 mm.

These images were acquired in axial phase and multi-planar reformatting was done on coronal and sagittal planes. A 3D-reconstruction of the non-enhanced, angiographic, nephrogenic, and excretory phase were performed as and when required. Two experienced radiologists evaluated each CECT and made note for: origin of renal arteries and aberrant renal vasculature, status of bilateral kidneys was assessed for their morphology and additional anomalies; excretion of bilateral kidneys and ureters opening into the urinary bladder. In the case of disagreement, the definitive decision was made by consensus.

Data was recorded and analyzed using Statistical Packages for the Social Sciences (SPSS version 23) for windows.

RESULTS

The average age of the study participants was 41.1 years. Regarding gender distribution, most of the participants were male (21), accounting for 55.2 % of the sample, while females comprised of 44.7 %. Among the 38 patients examined, 24 individuals (63.1 %) exhibited kidneys in their designated anatomical positions with normally developed renal parenchyma and collecting systems; among these the most diagnosed pathology was urolithiasis which was observed in 10 cases (26.3 %), followed by urothelial tumors in 9 patients (23.6 %), 3 patients had infection in renal tract, 2 patients had renal cysts. Notably, congenital renal anomalies were identified in 14 patients representing 36.8 % of the total sample. We broadly classified these anomalies as those related to migration irregularities, parenchymal development, and aberrations within the collecting system (Figure-1) (Table-I).

Specifically, 5 patients (13.1 %) manifested anomalies related to migration and fusion; of these 2 patients presented with crossed fused renal ectopia, the fused renal parenchyma being present in right iliac fossa, one of these demonstrated a calculus in lower fused moiety.

Both patients had a single draining ureter (Figure-2).

Three patients (7.8 %) exhibited migration anomalies in the form of horseshoe kidneys, the renal tissue showing fusion at lower pole in all these 3 patients. One of these patients demonstrated nephrolithiasis and grade II emphysematous pyelonephritis, other patient 11 years female demonstrated nephrolithiasis in right moiety and moderate hydronephrosis in left moiety (Figure-3). One patient with horseshoe kidney showed no complications.

Additionally, 3 patients (7.8 %) were diagnosed with ectopic pelvic kidneys, among whom one exhibited a duplex collecting system in the right pelvic kidney, another one had a contralateral retrocaval ureter with a pelvic left kidney (Figure-4) and the third patient displayed a right ectopic kidney with a normal left kidney. All these patients demonstrated aberrant vascular anatomy evident by accessory renal arteries arising from abdominal aorta, at bifurcation of aorta and contralateral or ipsilateral common iliac arteries.

Anomalies related to parenchymal development were evident as complete unilateral renal agenesis, hypoplasia and PUJ Obstruction. Unilateral left renal agenesis was observed in 3 patients (8.1 %), demonstrating empty renal bed with mild compensatory hypertrophy of contralateral kidney. One of these female patients with this condition displayed an associated Mullerian duct anomaly i.e. uni-cornuate uterus (Figure-5).

Aberrations within collecting system were manifested as duplex collecting system in 3 patients (8.1 %); one patient demonstrating duplex collecting system in right pelvic kidney, one patient showed a left duplex collecting system with bifid ureter (Figure-6) and third patient demonstrated an incomplete duplex collecting system with a bifid pelvis.

Congenital renal anomaly	Type of anomaly	Age (yrs.)	Gender	Right kidney	Left kidney	Association	Complication	Accessory renal artery
Anomalies of fusion & migration	Crossed fused renal ectopia	8	M	+	Fused with right kidney	Single draining ureter	Over-distended urinary bladder	From left common iliac artery
		21	M	+	Fused with right kidney	Single draining ureter	Nephrolithiasis	From bilateral common iliac arteries
	Horseshoe kidney	11	F	Both moieties fused at lower poles at LV4 level		Left hydronephrosis	Nephrolithiasis	From aorta & bifurcation
		52	F			-	Nephrolithiasis, Emphysematous pyelonephritis	From abdominal aorta
		45	M			-	-	From abdominal aorta
	Ectopic pelvic kidney	21	M	+	Pelvic	Right retrocaval ureter	Right hydronephrosis	Left common iliac artery
		38	M	Pelvic	+	Right Duplex collecting system	–	Right common iliac artery
		33	F	Pelvic	+	Right malrotation	Right hydronephrosis	Bifurcation of aorta
Abnormalities of parenchymal development	Unilateral renal agenesis	50	F	+	–	Unicornuate uterus	–	–
		33	M	+	_	_	Nephrolithiasis	_
		55	M	_	+	_	_	_
Aberrations in collecting system	DCS with bifid pelvis	17	F	Duplex CS	+	Right malrotation	_	-
	Duplex CS	38	M	Pelvic, DCS	+	Pelvic kidney	-	Common iliac artery
	DCS, Bifid ureter	15	M	+	DCS, Bifid ureter	-	-	From abdominal aorta

Table-I. Salient CT features of congenital renal anomalies

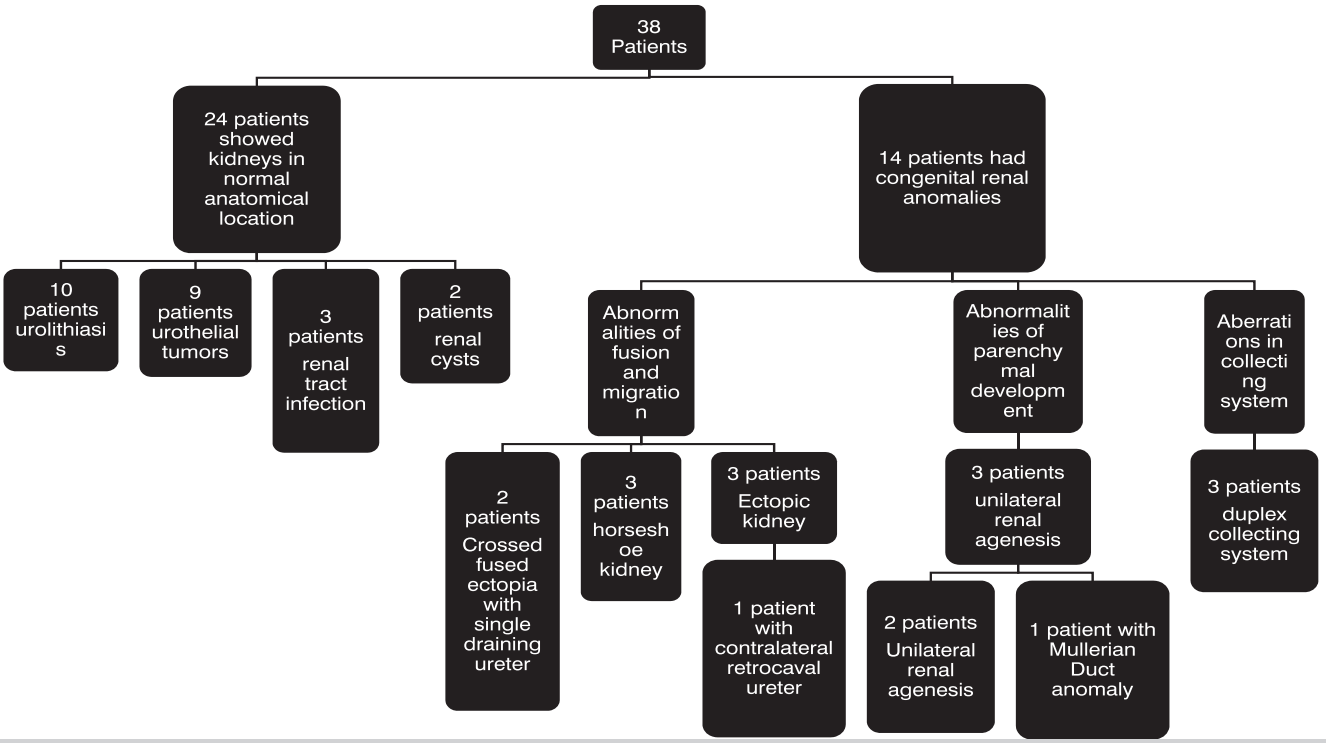

Figure-1. Distribution of renal disease pattern in study patients

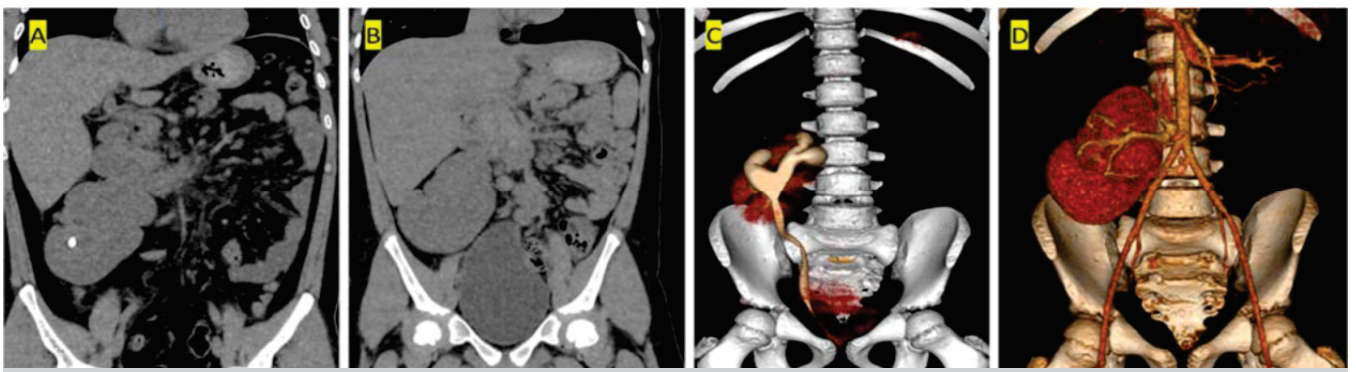

Figure-2. Crossed fused renal ectopia. A: Fused renal tissue in right iliac fossa, calculus in lower moiety. B: Right cross fused ectopia with overdistended urinary bladder. C: Excretory image showing single draining ureter. D: CT Angio showing low lying right renal artery and accessory renal artery from left common iliac artery.

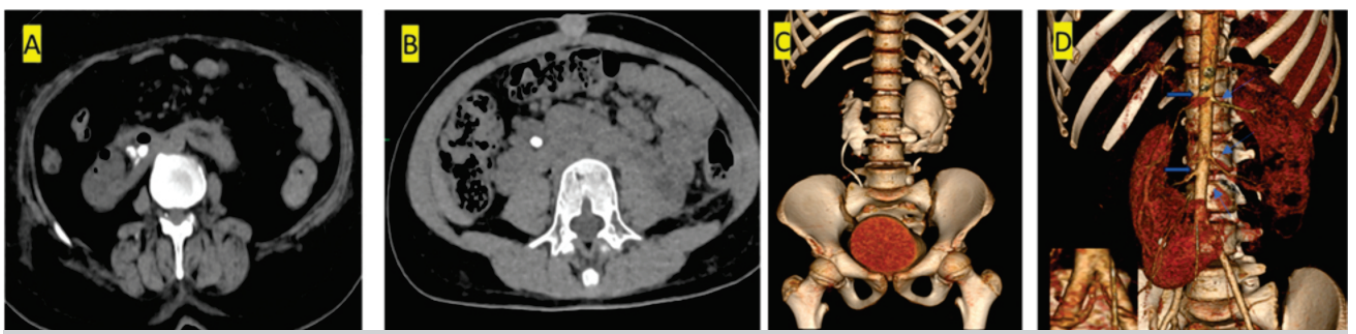

Figure-3. Horseshoe kidneys. A-B: Non-contrast images showing emphysematous pyelonephritis and nephrolithiasis. C: Excretory image showing Hydronephrosis in left moiety. D: Angiographic images demonstrating multiple accessory renal arteries (blue arrows) from the abdominal aorta, one from the bifurcation supplying the isthmus.

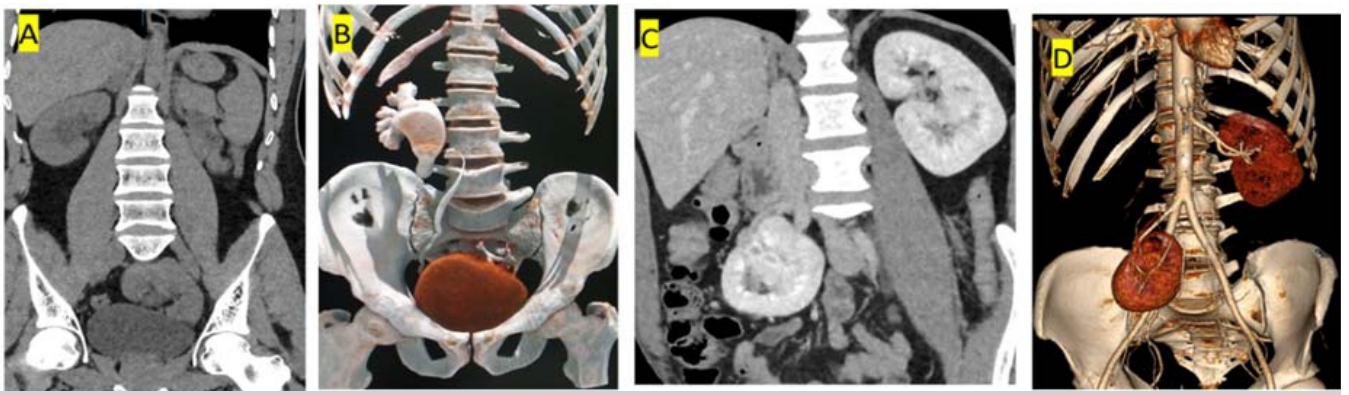

Figure-4. Ectopic pelvic kidney. A-B: Ectopic left kidney with right retro- caval ureter showing fishhook deformity. C: Right ectopic mal-rotated pelvic kidney with normal outline of bilateral renal parenchyma. D: Right pelvic kidney getting its blood supply from right common iliac artery after bifurcation of aorta.

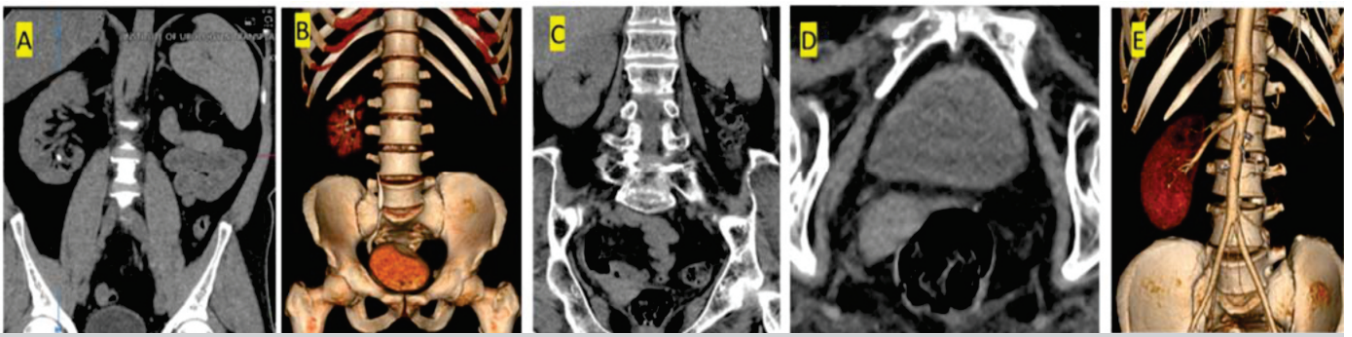

Figure-5. Unilateral renal hypoplasia. A: Nephrolithiasis in solitary right kidney. B: Single kidney draining into ureter. C-D: Left renal agenesis with absent left ovary, right unicornuate uterus. E: Single renal artery from abdominal aorta.

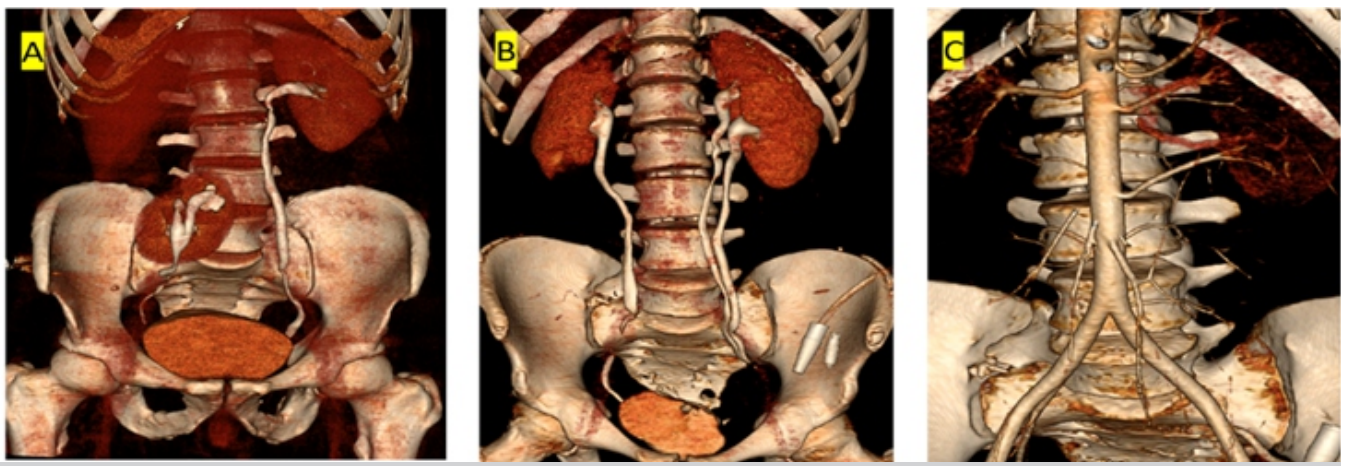

Figure-6. Aberrations in collecting system. A: Right pelvic kidney with duplex collecting system. B-C: Left duplex collecting system with bifid ureter. Accessory left renal arteries.

DISCUSSION

The prevalence of congenital renal anomalies as major birth defects emphasizes their clinical significance, constituting a substantial portion of congenital abnormalities.[12] Any disruptions or arrests in embryogenesis can give rise to a diverse range of congenital renal anomalies. This prevalence, estimated at 10-20% of all congenital abnormalities, underscores the need for heightened awareness and effective diagnostic strategies.[13] In the classification of these anomalies, a broad categorization into those related to parenchymal development, migration irregularities and aberrations within

the collecting system is made. Prenatal imaging emerges as a valuable tool for early detection, fetal hydronephrosis being the most common manifestation detected as early as 24 weeks of gestation.[14] On other extreme of spectrum can be bilateral renal agenesis which is fatal and not compatible with life. In this context, MDCT is crucial for evaluating congenital renal anomalies because it provides detailed cross-sectional images of the kidneys and surrounding structures. It helps visualize renal anatomy, identify urinary tract anomalies, assess vascular issues, detect complications, aid in preoperative planning, and monitor post-treatment progress. However, considering radiation exposure, its use should be balanced with potential risks, and alternative imaging methods may be considered in specific cases.

Migration anomalies include cross fused renal ectopia, horseshoe kidneys or ectopic kidneys.[15] We came across two patients of crossed fused renal ectopia. Both were male patients. The fused renal moieties seen in right iliac fossa, left kidney seen fused with the inferior pole of right kidney. One of these patients had calculus in inferior moiety. Both these patients showed aberrant renal vascular anatomy. On CT Urography excretory images, a single draining ureter was seen.

A horseshoe kidney configuration was identified in 3 patients, comprising 2 females and 1 male. In all cases, there was evidence of kidney fusion at the lower pole, specifically at the level of the LV4 vertebral body. Among these patients, one with a horseshoe kidney exhibited both nephrolithiasis and Grade II emphysematous pyelonephritis, another presented with nephrolithiasis in the right moiety along with obstruction in the left moiety, and the third patient had an uncomplicated horseshoe kidney. An ectopic kidney is a congenital anomaly characterized by the abnormal positioning of one or both kidneys outside their usual anatomical location in retroperitoneal space. We came across three patients with ectopic kidneys, two of these were male and 1 was female. One patient with left pelvic kidney had a rare association of Right Type 1 retro-caval ureter. The second patient showed duplex collecting system in right pelvic kidney. The third patient had a right pelvic kidney with a normal looking left kidney. The pelvic kidney was seen getting its blood supply from ipsilateral common iliac artery in two cases. Understanding the specific characteristics and potential complications associated with ectopic pelvic kidneys is essential for accurate diagnosis and appropriate management as pelvic ectopic kidney is prone to trauma due to its high mobility, so knowledge of its vascular supply is very important in case of any surgical intervention.

We came across three patients of unilateral renal agenesis, left kidney being absent in two patients, one patient showed absence of right kidney. One of these had nephrolithiasis in the right normal kidney while the female patient 50 years of age had associated Mullerian duct anomaly manifested by right unicornuate uterus and agenesis of left ovary and left kidney. It underscores the correlation between urinary and genital anomalies. When renal agenesis is identified, it's crucial to investigate for associated genital anomalies, and vice versa.[16] In these patients there was non-visualization of corresponding renal artery on CT Angiography. Bilateral adrenal glands were seen in their normal supra-renal location in all these patients.

Aberrations in the collecting system encompass duplex collecting system, bifid pelvis, or complete duplex collecting system.[17] The categorization of duplex kidney anomalies depends on the level of fusion, including Duplex Kidney, Duplex Collecting System with Single Ureter, Bifid Ureter (Ureter Fissus) and Double Ureter (Complete Duplication).[18] We came across 3 patients with collecting system abnormalities. One of these patients had duplex collecting in pelvic kidney while other patient had duplex collecting system with bifid ureter. On patient had duplex collecting system with bifid pelvis, this patient could not undergo contrast enhanced CT scan due to deranged RFTs.

CONCLUSION

Constituting 10-20% of major birth defects, congenital renal anomalies emphasize the need for effective diagnostic strategies. MDCT emerges

as a pivotal tool, offering high-resolution imaging and playing a key role in detecting anomalies, assessing complications, evaluating aberrant vessels, and guiding interventions. However, considering radiation exposure, its use should be balanced with potential risks.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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2	**Riffat Raja:** Conceptualization of project, data collection, literature search, statistical analysis, drafting, revision, writing of manuscript.
3	**Saba Binte Kashmir:** Conceptualization of project, data collection, literature search, statistical analysis, drafting, revision, writing of manuscript.
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