Research Article

Clinical Profile, Diagnostic Challenges and Current Care for Children with Chronic Kidney Disease: A Longitudinal Study from a Tertiary Center in Egypt

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Abstract

Background: Pediatric CKD data are scarce in low-/middle-income countries. We aimed to describe the magnitude of the disease, the challenges in diagnosis, its burden and the current care provided at Mansoura University Children's Hospital. **Methods:** Prospective cross-sectional study (Aug 2023–Aug 2025, n=550, age 1 month–18 years). eGFR by Schwartz formula; end points. **Results:** Median age 10 years, 61% male. CAKUT was the leading cause (67%), followed by undetermined (10%). Advanced CKD (stages IV–V) present in 41.8%. Hypertension in 19.8%. Overall, only 6.9% received a transplant; 27% required dialysis; mortality 4.9%. **Conclusion:** CAKUT dominates pediatric CKD in this Egyptian cohort. Hemodialysis remains the most commonly used for renal replacement therapy. Early detection is urgently needed.

Keywords: Children, Pediatrics, CKD, CAKUT, Egypt, Burden, Dialysis, Renal replacement therapy

1. Introduction

Chronic kidney disease (CKD) represents a substantial global public health problem, affecting over 10% of the world-wide population and imposing a continuously growing economic burden. (1,2) Although the epidemiological profile of CKD has been extensively documented in adult populations, corresponding data for pediatric patients remains distinctly sparse. Most insights into childhood CKD are extrapolated from major kidney replacement therapy (KRT) registries like the ESPN/ERA in Europe and the USRDS in the USA, (3-5) leaving a significant knowledge gap regarding the actual incidence of the disease in children, especially in developing regions. (6)

The ideal timing and method for KRT is a complex process influenced by clinical presentation, laboratory results, practical constraints, and the shared preferences of families and clinicians.(7) The precise threshold for initiating KRT remains widely debated. Dialysis, while beneficial, only partially mitigates CKD complications and carries specific treatment-associated risks.(8) For pediatric patients, preemptive transplantation is a highly utilized KRT option. This approach yields superior survival rates and lower cardiovascular morbidity, though these benefits must be weighed against the need for early, lifelong immunosuppression and its subsequent long-term sequelae.(7, 9, 10)

In resource-constrained settings, the primary obstacles to effective management include the delayed detection of childhood CKD, challenges in diagnosis, lack of expedited specialist referral, and inadequate access to comprehensive disease management and dialysis services. Systemic disparities significantly hinder the continuum of care, disrupting progress from the initial diagnosis of kidney failure through to eventual transplantation across national, institutional, and socioeconomic strata.(11, 12) In light of these challenges, We aimed to describe the magnitude of pediatric CKD problem and describe the current care at Mansoura University Children's Hospital.

PATIENTS AND METHODS

This prospective, descriptive cross-sectional study was conducted at the Mansoura University Children's Hospital Nephrology Unit between August 2023 and August 2025. The study cohort comprised 550 pediatric patients (aged 0–18 years) diagnosed as chronic kidney disease following at outpatient clinic, including 84 patients receiving

maintenance hemodialysis at our dialysis unit. Clinical data collection included demographic profiles, pathological diagnoses, and echocardiographic parameters, with whole exome sequencing (WES) utilized for genetic analysis in selected cases. Disease progression and CKD staging were monitored using the Schwartz formula to calculate the estimated glomerular filtration rate (eGFR). Clinical endpoints were categorized as stable follow-up, initiation of RRT, renal transplantation, mortality, or loss to follow-up (defined as missing >2 consecutive appointments). Patients with acute kidney injury or incomplete medical records were excluded from the analysis.

Statistical Analysis

Data were analyzed using SPSS version 26. Categorical variables were summarized as frequencies and percentages, while numerical variables were expressed as mean ± standard deviation for normally distributed data and median with range and interquartile range for non normally distributed data. Normality was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests, with statistical significance set at $p < 0.05$. Appropriate statistical tests were applied according to data type and distribution, including Chi square, Fisher's exact, and Monte Carlo tests for qualitative variables; Mann–Whitney U and Kruskal–Wallis tests for non parametric comparisons; paired t-test and Wilcoxon signed rank test for paired data; and Spearman's rank correlation to assess associations between non normally distributed or ordinal variables.

Ethical Consideration

The study was approved by Institutional Research Board of Faculty of Medicine, Mansoura University (Approval code; MD.23.02.743). Written informed consents were obtained from legal guardians of all patients before enrollment in the study. Verbal consents were obtained from children and adolescents under 16 years of age whenever possible. Confidentiality of the data of the study participants was ensured.

RESULTS

The current study included 550 children, 336 (61.1%) of them were males, and 214 (38.9%) were females with a median of 10 years ranging between 1 month and 18 years with interquartile range (6-13.5). 56% of the patients were from Dakahlia governorate while 34.7% of cases were from Delta region governorate including "Gharbia, Menofia, Kafr el-Sheikh, Damietta, Beheira, and Qalyubia" and 9% from upper-Egypt and other governorates as described in table (I).

Table I: Demographic characteristics of the studied pediatric CKD cohort (N=550)

	n	%
Age at the start of the study (in years)		
median (min-max)	10(0.1-18)	
(IQR)	(6-13.5)	
Sex		
Males	336	61.1
Females	214	38.9
Governorate		
Dakahlia governorate	310	56.4
Delta Region governorates	191	34.7
Others	49	9

IQR: Interquartile range

The analysis of primary kidney diseases within this cohort identifies Congenital Anomalies of the Kidney and Urinary Tract (CAKUT) as the overwhelming driver of pediatric chronic kidney disease (CKD) accounting for 67% of the total population. Within the CAKUT subgroup, posterior urethral valve (PUV) was the most prevalent specific diagnosis (17.5%), followed by solitary kidney and polycystic kidney at 9.7%, 9.3 respectively. As described in table (II) Undetermined renal parenchymal etiology represented 10% of the cohort, while Glomerular disorders and tubular disorders represented smaller segments of the cohort at 8% and 6%, respectively. Among these, nephrotic syndrome was the leading glomerular pathology. While Bartter syndrome and renal tubular acidosis were the primary identified tubular conditions, others including oxalosis, nephronophthisis and cystinosis were also present. Acquired and miscellaneous group represented 9.3% including (Hemolytic uremic syndrome, Post COVID 19, Renal Angiomyolipoma, Undiagnosed renal stones, Sarcoidosis and 1ry antiphospholipid syndrome)

Table II: Etiology of chronic kidney disease in the studied cohort (N=550)

	N	%
CAKUT	**367**	**67%**
Posterior urethral valve	96	17.5
Solitary kidney	53	9.7
Polycystic Kidney	51	9.3
Neurogenic bladder	45	8.2
Vesicoureteral reflux	43	7.8
Others (Dysplastic, PUJO, others)	28	5.1
Glomerular disease	**44**	**8**
Nephrotic Syndrome	22	4.0
Glomerulonephritis	18	3.13
Others (Lupus, Alport)	4	0.8
Undetermined etiology	**56**	**10**
Tubular	**32**	**6%**
Bartter Syndrome	9	1.6
Renal Tubular Acidosis	6	1.1
Others (Oxalosis, Nephronophthisis, etc)	17	3.1
Acquired/others	**51**	**9.3**
Hemolytic uremic syndrome	27	4.9
Others	24	4.4

PUJO: Pelvi-Ureteric Junctional Obstruction

The clinical profile of the cohort revealed a high rate of silent progression as illustrated in table (III), with 34.5% of patients discovered accidentally and 27.3% diagnosed antenatally, while specific renal symptoms represented only 19% of our patient's initial clinical presentation. Comorbidity analysis showed that hypertension was present in approximately 19.8% of the cohort, with the vast majority being successfully managed through medical therapy. The hematological burden was notable, as nearly 31% of patients had history of blood transfusions during the disease course. Furthermore, systemic complications such as bone osteodystrophy (8.5%) and thyroid dysfunction (2.9%) highlight the multifaceted nature of pediatric CKD management beyond primary renal care.

Table III: Clinical characteristics and comorbidities of the studied cohort (N=550)

	n	%
Initial Clinical Presentation		
Asymptomatic/Accidental discovery	190	34.5
Antenatal diagnosis	150	27.3
Renal Symptoms	107	19.5
Non-specific symptoms	103	19.0
Hypertension Status		
Normotensive	441	80.2
Controlled on medication	104	18.9
Uncontrolled on medication	5	0.9
Hematological & Therapeutic History		
History of blood transfusion	170	30.9
Prior immunosuppressive therapy	34	6.2
Prior therapeutic plasma exchange	12	2.2
Associated Complications		
Bone osteodystrophy	47	8.5
Thyroid dysfunction	16	2.9
Positive HCV serology	3	0.5

Analysis of the echocardiographic findings (Table IV) categorized cardiac conditions based on their association with the clinical state of chronic kidney disease (CKD). Of the 211 patients (38% of the total cohort) who underwent echocardiography, 140 (66%) exhibited findings related to CKD, while 16 (8%) presented with cardiac

findings unrelated to their renal status. Normal echocardiographic results were observed in the remaining 55 patients (26%).

Table IV: Echocardiographic findings of the studied cohort

Echo finding	N	%
Normal	55	10
Abnormal	156	28.36
No echo	339	61.6
Abnormal		
Finding related to CKD	**140**	
LVH	105	49.7
valve regurgitation	3	1.4
Impaired systolic function	28	13.3
Pericardial effusion	2	0.9
Infective endocarditis	2	0.9
Finding not related to CKD	**16**	
ASD	3	1.4
AVSD	2	0.9
PDA	1	0.5
TOF	2	0.9
Pulmonary stenosis	1	0.5
Dilated coronaries	2	0.9
Aortic valve stenosis	1	0.5
Aortic coarctation	2	0.9
Pulmonary Hypertension	1	0.5
Cardiac myxedema	1	0.5

LVH: Left Ventricular Hypertrophy, ASD: Atrial Septal Defect, AVSD: Atrioventricular septal defect, PDA: Patent Ductus Arteriosus, TOF: Tetralogy of Fallot

Renal biopsy was indicated in 143 patients (26% of the cohort). Of these, 51 cases were eligible and proceeded to biopsy. Histopathological analysis revealed glomerular pathology in 29 cases and tubular pathology in 10 cases. Additionally, 8 biopsies demonstrated concurrent glomerular and tubular involvement, while isolated vascular affection was noted in only 4 cases as described in table (V).

Table V: Biopsy state & Histopathological findings of the studied cases

Biopsy	N	%
Not indicated	407	74.0
Risky biopsies	92	17.0
Biopsied cases	51	9.0
Glomerular	29	
No abnormalities	6	12
FSGS	4	8
Cellular crescentic GN	2	4
Chronic diffuse crescentic GN	2	4
Focal global sclerosis	1	2
Collagen IV abnormality	5	10
Basket weave appearance	1	2
Dense deposit disease	1	2
Membranous Nephropathy	3	6
Diffuse mesangial sclerosis	1	2
Diffuse cortical sclerosis	1	2
Lupus nephritis “Proliferative class”	2	4
Tubular	10	
Oxalosis	1	2
Chronic tubulointerstitial nephritis	8	16
Granulomatous interstitial nephritis	1	2

Vascular		
Thrombotic microangiopathy	4	8
Glomerular + Tubular		
Sclerotic glomeruli & chronic tubulointerstitial fibrosis	8	16

FSGS: Focal segmental Glomerulosclerosis

The investigation into the genetic background of the cohort revealed that 11.3% of patients had a positive family history of renal disease. Despite the known utility of genetic diagnostics in pediatric nephrology, significant barriers to access remain evident in this population. While genetic testing via Whole Exome Sequencing (WES) was clinically indicated in 18.4% of the cases, it was not performed, primarily due to financial constraints and limited availability of specialized genetic services. Among the small subset of the cohort (5.4%) that successfully underwent WES, the diagnostic yield was remarkably high, with 5% of the total cohort receiving a molecularly confirmed positive result compared to only 0.4% who tested negative. The most frequent mutation observed was in the CFHR1 & 3 genes (30%, n=8), which was exclusively associated with Hemolytic Uremic Syndrome (HUS). This was followed by AGXT-1 mutations (22%, n=6), linked to nephrocalcinosis and stone formation. Most of the identified variants were classified as pathogenic (Table VI).

Table VI: Genetic background and utilization of WES in the study population

Family history			
Negative		488	88.7
Positive		62	11.3
WES indications and application			
Not needed		422	77
Needed but not done		101	18.4
Done with positive result		25	5
Done with negative result		2	0.4
Types of gene mutations and clinical phenotype (N= 25)			
Gene	**N (%)**	**Clinical presentation**	**Pathogenic**
CFHR 1 &3	8 (30%)	HUS	Pathogenic
AGXT-1	6 (22%)	Nephrocalcinosis / stone passer	Pathogenic
IFT140	4 (15%)	Anemia	Pathogenic
LCAT	1 (4%)	Nephrotic Syndrome	Pathogenic
CASP10	1 (4%)	Nephrotic Syndrome	VUS
OCRL	1 (4%)	Nephrotic Syndrome	VUS with pathogenic evidence
NPHS2	1 (4%)	Nephrotic Syndrome	Pathogenic
NUP93	1 (4%)	Proteinuria	VUS with pathogenic evidence
INVS	1 (4%)	Asymptomatic	Pathogenic
COQ8B	1 (4%)	Asymptomatic	Pathogenic

WES: Whole Exome Sequencing, HUS: Hemolytic Uremic Syndrome, VUS: Variant of unknown Significant

The correlation between CKD etiology and associated syndromes (Table VII) demonstrated significant syndromic diversity within the cohort. While most cases across all etiologies were non-syndromic, specific associations were observed with CAKUT Group representing the highest variety of associated syndromes, including Bardet-Biedl (1.6%), Prune Belly (1.1%), and isolated cases of Trisomy X, Goldenhar, and VACTERL. Undetermined Etiology notably contained the highest frequency of Joubert syndrome (9.3%) and Senior-Løken syndrome (3.7%), often presenting as nephronophthisis leading to advanced CKD before a primary renal diagnosis could be established. Miscellaneous & Tubular Groups included associations with Down syndrome (5.9%) and Gitelman syndrome (17.4%), respectively.

Table VII: Association Between Primary CKD Etiology and Syndromic Presentation within the Study Cohort

		Etiology	**Test of significance**

		CAKUT	Glomerular Disease	Hereditary/ Genetics	Undetermined	Miscellaneous	Tubular	
Not Syndromic	N	345	41	11	45	47	19	Mc=240 P=0.001 *
	%	93.8%	100.0%	84.6%	83.3%	92.2%	82.6%	
Dysmorphic but non syndromic	N	7	0	0	2	0	0	
	%	1.9%	0.0%	0.0%	3.7%	0.0%	0.0%	
Bardet Beidel Syndrome	N	6	0	0	0	0	0	
	%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	
Prune Belly Syndrome	N	4	0	1	0	0	0	
	%	1.1%	0.0%	7.7%	0.0%	0.0%	0.0%	
Down Syndrome	N	2	0	0	0	3	0	
	%	0.5%	0.0%	0.0%	0.0%	5.9%	0.0%	
Trisomy X	N	1	0	0	0	0	0	
	%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	
Joubert Syndrome	N	0	0	0	5	0	0	
	%	0.0%	0.0%	0.0%	9.3%	0.0%	0.0%	
Bartter Syndrome	N	0	0	0	0	0	4	
	%	0.0%	0.0%	0.0%	0.0%	0.0%	17.4%	
Goldenhar Syndrome	N	1	0	0	0	0	0	
	%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	
Alport Syndrome	N	0	0	1	0	0	0	
	%	0.0%	0.0%	7.7%	0.0%	0.0%	0.0%	
Sanjad Sakatti Syndrome	N	0	0	0	0	1	0	
	%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	
Mainzer Saldino	N	0	0	0	2	0	0	
	%	0.0%	0.0%	0.0%	3.7%	0.0%	0.0%	
Turner Syndrome	N	1	0	0	0	0	0	
	%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	
Pellagra Syndrome	N	1	0	0	0	0	0	
	%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	

MC: Monte Carlo test, *statistically significant

Table VIII analyzes the eGFR progression throughout the study period, where at the start of the cohort study CKD stage I was reported in 168 (30.5%) patients, stage II was reported in 58 (10.5%) patients, stage III (a+b) was reported in 94 (17.1%) patients, stage IV was reported in 60 (10.9%) patients, and stage V was reported in 170 (30.9 %) patients as shown in table (8). And there was no statistical significance between the start and the end of the study (P=0.633). The GFR statistically increased from the start of the study to its end (P=0.001).

Table VIII: Longitudinal Assessment of CKD stages and eGFR trends among the study cohort

	n	%
Renal replacement therapy modality		
Conservative measures	406	73.82
Hemodialysis (HD)	141	26.0
Peritoneal Dialysis (PD)	3	1.0
Dialysis patients' number	N=144	
Dialysis duration median (IQR)	2.0(0.6-4.0)	
Dialysis Access		
Arterio-venous Fistula	122	85.3
Permanent HD Catheter	19	12.6
Permanent PD catheter	3	2.1
Dialysis complications		
Yes	83	58
No	61	42

Dialysis related Complications		
Excess Intradialytic weight gain	38	26.6
Intradialytic hypertension	10	7.0
Hypoglycemia	3	2.1
Peritonitis	1	0.7
Access Related Complications		
AVF thrombosis	3	2.1
AVF aneurysm	1	0.7
CVL problems	11	7
Others	16	11.2

IQR: Interquartile range, *statistically significant, Z: Wilcoxon signed rank test, HD: Hemodialysis.

A comprehensive overview of the Renal Replacement Therapy (RRT) landscape within our study cohort is described in table (IX), highlighting a significant majority of the cohort (74.0%) remained on conservative management, indicating a large population of pre-dialysis CKD patients. Among those requiring RRT, Hemodialysis (HD) is the primary modality (26.0%), while Peritoneal Dialysis (PD) is vastly underutilized (1.0%).

Regarding the dialysis access, Arteriovenous Fistula (AVF) was the most frequent access type (85.3%), which is clinically favorable while those failed to have AVF necessitating utilization of permanent HD catheter was 12.6%.

As for dialysis complications profile, over half of the dialysis patients (58%) experienced complications, with excess intradialytic weight gain (38%) representing the leading issue. Beside vascular Access Issues reflecting the technical difficulty of maintaining long-term vascular access in pediatric patients, in addition to other complications including tertiary hyperparathyroidism, severe cardiac affection, refractory hypertension & psychological troubles related to chronic disease.

Table IX: Renal replacement therapy, Modalities, Access Characteristics and clinal complications in the cohort

	n	%
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Peritonitis	1	0.7
Access Related Complications		
AVF thrombosis	3	2.1
AVF aneurysm	1	0.7
CVL problems	11	7
Others	16	11.2

IQR: Interquartile range, HD: Hemodialysis, PD: Peritoneal dialysis, SVC: Superior Vena cava, AVF: Arterio-venous Fistula, CVL: Central Venous line.

The largest portion of the cohort experiencing relative stability. Specifically, 44.2% (n=243) of the patients did not require an urgent start for transplant preparation and were kept on conservative management with their routine follow-up at the CKD clinic. Regarding the transplantation pathway, 6.9% (n=38) of the cohort successfully underwent transplantation, while another 12.5% (n=69) were still actively preparing for the procedure. However, a notable segment faced challenges during the workup process; 13.6% (n=75) failed transplant preparation but remained under conservative CKD clinic care, and another 5.6% (n=31) failed preparation and ultimately required dialysis. Finally, the study tracked cohort attrition and definitive clinical endpoints, recording a mortality rate of 4.9% (n=27) alongside a 7.6% (n=42) loss to follow-up, while 4.5% (n=25) of the patients aged out of the program and successfully transitioned to adult nephrology care. By the end of the study 38 patients out of 213 who were eligible for transplantation did renal transplantation, while 106 out of the 292 who were having barrier for transplantation failed to continue preparation, 69 patients were in the processing of renal transplant preparation, 25 patients transferred to adult nephrology care, 42 patients lost follow up and unfortunately 27 patients died during the study time: table (X).

Table X: Clinical Outcomes and Final Disposition of the Study Cohort

End points		
Following at CKD clinic	**418**	
Not needing urgent transplant	243	44.2
Still preparing for transplantation	69	12.5
Failed preparation & now on dialysis	31	5.6
Failed preparation & following at CKD clinic	75	13.6
Not following at CKD clinic	**132**	
Did Transplantation	38	6.9
Death:	27	4.9
Unknown	12	2.2
Septic Shock	8	1.5
Access failure	4	0.7
Infective endocarditis	2	0.4
Intracranial hemorrhage	1	0.2
Loss of follow up	42	7.6
Transferred to adult nephrology	25	4.5
Total	**550**	**100.0**

DISCUSSION

Chronic kidney disease (CKD) is one of the most prevalent non-communicable health concerns, affecting over 10% of the global population, amounting to more than 850 million individuals.(2) Most data on chronic kidney disease children are from the developed world. Based on the current kidney registries and epidemiological studies, the prevalence of pediatric CKD is approximately 30–100 cases per million age-related population, suggesting that about 1 in every 10,000 children has CKD.(13) This number may be underreported as well, with reported cases in resource-limited countries likely confined to patients at tertiary care centers, or going unreported altogether.(14)

In the absence of a national registry, the exact incidence and burden of CKD in children in Egypt is not known. A review of the available literature reveals a paucity of information on the incidence and prevalence of CKD in Egyptian children, the magnitude of disease progression. We aimed to describe the current magnitude of CKD problem in pediatric age group and the current care provided at Mansoura University Children's Hospital as well as describing the barriers against providing renal transplantation for all CKD children reaching the primary end point of the study in describing the barriers that had faced us in establishing kidney transplantation service at Mansoura university children's hospital and how we managed to solve some.

We collected data of 550 patients who were receiving care at Mansoura University children's hospital (466 patients who were following at our CKD outpatient clinic and other 84 patients from our dialysis day care unit) over a period of 2 years from August 2023 till August 2025.

Mansoura university children's hospital is a tertiary hospital and provides a wide range of medical service through 13 subspecialities including nephrology and dialysis unit that can provide service to Dakahlia governorate children and other governorates as well, where 56 % were from Dakahlia & 44% of the studied cases were from other governorates.

The median age of participants was 10, with 61% males and 38% females. Male preponderance in our patients is in accordance with other studies from Egypt.(1, 15, 16) This was also in line with the database collected from the global burden of disease from 1990 to 2021.(17) This is largely attributed to the high incidence of congenital urological malformations.

In our study, CAKUT were the leading etiology of kidney disease, accounting for 67% (367) of the patients. These findings align with research by Kansakar et al. on 352 children.(18) and a large-scale 2012–2013 Egyptian multi-center study of 1,018 children, which identified obstructive uropathy as the primary cause of CKD (1). While adult CKD typically stems from acquired, long-term metabolic or lifestyle factors like diabetes and hypertension, pediatric cases are predominantly driven by developmental and congenital structural defect. However, our results differ from another Egyptian study of 142 hospitalized pediatric patients; in that cohort, glomerular diseases were the primary etiology (51.2%), with CAKUT ranking second (27.3%).(16) Table XI compares the causes of pediatric CKD across various studies.

Table (XI): Comparative analysis of chronic kidney disease causes in children across various international studies

Etiology (%)	Date of study						
	2008	1994-2007	1997-2007	2003	2005	2012	2025
	ESPN/ERA-EDTA registry(19)	USA NAPRTCS (20)	Iran (21)	India (22)	Kuwait (23)	Egypt (1)	MUCH study
Urological anomalies	36	48	50.4	57.9	61.9	46	67
glomerulonephritis	15	14	6.5	27.5	5.2	15.3	8
Hereditary	22	10	17.2	7.5	21	6.7	6
Hemolytic uremic syndrome	6	2	0.7	1.6	2.3	3.6	4.9
Unknown	7	3	10.8	5.7	1.7	20.6	10

Among patients with CAKUT, the commonest disease was posterior urethral valve (PUV) in 96 (17.5% of the total cohort), followed by solitary kidney in 53 (9.7%) patients. Our finding that PUV predominates among CAKUT subtypes is consistent with two other Egyptian (24) (15). However our results differ from those of Kansakar et al. who reported Vesicoureteral reflux (VUR) as the most common CAKUT in a cohort of 352 children (18) and from other studies that identified pelvi-ureteric junction (PUJ) obstruction as the leading anomaly(25).These discrepancies likely reflect differences in referral patterns, diagnostic practices, and regional variations in disease prevalence. The high rate of CAKUT-related CKD in this Egyptian cohort underscores the importance of early urological intervention and the potential impact of improved antenatal screening, which already accounted for 27% of initial diagnoses in this study.

In the present cohort, nephrotic syndrome (NS) was the most common glomerular disorder, occurring in 22 patients (4% of the total cohort). Among tubular disorders, Bartter syndrome was identified in 1.6% and renal tubular acidosis (RTA) in 1.1% of patients. Our findings align with Sayed et al., who reported nephrotic syndrome as the predominant glomerular disease, affecting 122 of 134 patients (91%) with glomerular disorders (15), In contrast, two other studies found glomerulonephritis to be the most frequent glomerular diagnosis (18, 24). These variations may be attributed to differences in cohort composition (e.g., hospitalized vs. outpatient populations) and the availability of renal biopsy for definitive diagnosis.

In our cohort of 550 patients, only 27.3% (n=150) were diagnosed antenatally, a notably lower rate compared to previous studies reporting prevalence of 63.9% (15) and 60% (24), likely due to differences in access to specialized fetal medicine services. An analysis of initial clinical presentations revealed that 34% of the group was entirely asymptomatic at diagnosis, while the remainder were identified via antenatal screening (27%), nonspecific

symptoms (19%), or distinct renal symptoms (19%). Our asymptomatic detection rate aligns with a Korean school screening program (36.9%) (26). These findings highlight a critical clinical challenge: a substantial portion of the pediatric population experiences silent progression of renal impairment. Consequently, this leads to late presentation, which severely limits therapeutic options, exacerbates comorbidities, and increases the rate of related complications. Ultimately, these data underscore the paramount importance of robust early screening protocols to facilitate timely detection and intervention.

In our study Hypertension was reported in 109 (19.8%). Nearby prevalence was reported by Radhakrishna et al. study on 81 patients with CAKUT; hypertension was found in 27% of cases.(25) Higher prevalence (60%) of children was reported by Masalskienė et al. and Shaimaa et al. reporting hypertension in 175 patients (47.9%).(15, 27) Variations in reported hypertension rates can largely be explained by the heterogeneity of the study populations. Specifically, cohorts with a high proportion of glomerular diseases (e.g., glomerulonephritis) typically exhibit higher rates of hypertension than CAKUT-dominated cohorts. Additionally, intrinsic and lifestyle factors, such as genetic predisposition and dietary sodium consumption, may further drive these differences.

Regarding hematological health, 30.9% of our patients required blood transfusions, with 22.4% of that group need more than three interventions. While this indicates significant morbidity, it remains lower than the anemia rates as reported by Chidambaram et al. and Sayed et al. (15, 28)

In our study, 38% had echocardiographic examination, with nearly two-thirds (66%) showing findings directly related to their CKD status. The prevalence of Left ventricular hypertrophy (LVH) has been reported as 20–30%,increasing to 85% in patients on maintenance dialysis LVH also persists following renal transplantation, affecting up to 50% of patients.(29)

Our findings showed that systolic dysfunction affected 13.3% of the pediatric CKD patients studied, appearing less frequently than LVH but still representing a major concern. Similarly, Chinali et al. identified cardiac abnormalities in 25% of children with stage 2–4 CKD.(30) In contrast, Khandelwal et al. reported a higher prevalence of systolic dysfunction at 32.9% (47 patients), likely because their study focused on children with advanced (stage 4–5) CKD approaching kidney replacement therapy.(31)

Late clinical presentation significantly limits the diagnostic utility of renal biopsies. In our cohort, 10% of patients presented with an undetermined etiology, primarily because advanced-stage renal failure often manifests with shrunken, echogenic kidneys, rendering biopsy high-risk and clinically unfeasible. While 143 patients (26%) were initially considered eligible for a renal biopsy, the procedure was safely performed in only 51 cases. For the remaining 92 patients (17% of the total cohort), biopsies were deferred due to the anticipated low diagnostic yield and elevated risk associated with late presentation. These limitations align with findings from an Egyptian study by safouh et al which reported an unidentified etiology in 20.6% of patients for similar reasons (1).

Histopathological analysis of the biopsied cases revealed a strong predominance of glomerular findings (29 cases) over tubular and vascular issues, consistent with global pediatric registry data.(32) Notably, the prevalence of Focal Segmental Glomerulosclerosis (FSGS) was relatively low (8%) compared to other regional studies. (33) (34) In contrast, Chronic Tubulointerstitial Nephritis (TIN) was observed at a disproportionately high rate (16%), compared to some single-center studies that report TIN rates as low as 1.7% to 5% (35). This might suggest a higher prevalence of reflux nephropathy or chronic pyelonephritis in our patients.

Our detection of Collagen IV abnormalities in 10% of the glomerular cases using Electron Microscopy (EM) provides a more robust diagnostic yield than general genetic screening of CKD populations, which typically identifies COL4A mutations in only 3% of adult cases. (36) These findings underscore the critical role of EM in bridging diagnostic gaps, particularly in distinguishing structural basement membrane defects from cases that might otherwise be misdiagnosed as idiopathic FSGS under light microscopy alone.

The genetic architecture of pediatric CKD is complex, with over 600 monogenic causes identified (37, 38). Among the small subset of the cohort (5.4%) that successfully underwent WES, the diagnostic yield was remarkably high, with 5% of the total cohort receiving a molecularly confirmed positive result compared to only 0.4% who tested negative. Our findings reveal a distinct profile compared to international cohorts. Mallett et al. reported Alport syndrome mutations in 30% of their genetic diagnoses,[35] yet Alport mutations were entirely absent in our

cohort. Conversely, our yield for aHUS related genes (CFHR1/CFHR3) was substantially higher than the 25% reported by Mallett et al., suggesting regional or phenotypic uniqueness (39) Additionally, primary hyperoxaluria type 1 was identified in six cases (1.1%), a critical finding that impacts early vitamin B6 therapy and transplant planning. These findings underscore a critical "diagnostic gap" in our clinical setting. The high positivity rate among those tested suggests that expanded access to WES could significantly improve diagnostic precision, inform genetic counseling for families, and potentially guide personalized management strategies for a larger portion of pediatric CKD patients in Egypt.

The study demonstrated a statistically significant correlation ($p < 0.001$) between pediatric CKD etiologies and a diverse range of associated syndromes, emphasizing the diagnostic value of extra-renal manifestations. While the CAKUT group exhibited the widest variety of syndromes (notably Bardet-Biedl and Prune Belly), the Undetermined Etiology group was characterized by a high prevalence of Joubert and Senior-Løken syndromes, which often progress to advanced renal failure before a primary diagnosis is established. Given these findings, a comprehensive syndromic evaluation is essential for all pediatric CKD patients to accurately identify underlying genetic and developmental pathologies.

Progression of CKD to ESKD is influenced by multiple factors, including the etiology of CKD, the initial stage at presentation, and the intensity of management of associated complications (40). The median eGFR at initial presentation and at end of the study was 39, 50 mL/min/1.73 m2 respectively. Our data on the progression of chronic kidney disease stages revealed shifting distribution across the stages of renal health with improvement in early stages where there was a notable increase in patients classified as stage I, rising from 30.5% to 39.1% that could be explained by the number who had underwent renal transplantation, beside the intensive measures carried out regarding mitigation of reversible acute factors including management of nephrotoxic exposure, infection and correction of volume status with administration of nephroprotective agents like ACE inhibitors or ARBs in some cases.

While the general trend showed improvement, the data also revealed a bimodal outcome. The increase in patients requiring hemodialysis (from 18.5% to 22.2%) indicates that while many patients responded positively to treatment, a smaller subgroup with advanced disease continued to progress to end-stage renal disease (ESRD). This explains why the GFR values improved significantly on an individual level, even as the overall stage distribution remained statistically stable.

During the treatment period, 27% of our patients required dialysis initiation with dependence on hemodialysis in nearly all cases in our center. This aligns closely with the 25.5% prevalence reported in Nigeria.(41) However, our rate us notably lower than 93.6 % observed in a 2015 Egyptian study.(1) This difference is likely due to varying proportions of patients with advanced renal disease; advanced stages accounted for 42% of our study groups, compared to 76% in the other Egyptian study involving chronic kidney disease children from 11 universities over a period of two years.

The distribution of RRT modalities in this study reflects a strong preference for hemodialysis (26%) over peritoneal dialysis (1%), with a high rate of successful AVF maturation (85.3%). However, the high incidence of dialysis-related complications (58%)—predominantly intradialytic weight gain and hypotension—highlights the significant physiological burden RRT imposes on pediatric patients. These findings suggest a need for more intensive nutritional counseling to manage interdialytic weight gain and a potential re-evaluation of PD as a more stable alternative for this vulnerable demographic.

Dialysis imposes a significant multifaceted burden, encompassing both clinical and economic dimensions. Irrespective of lower incidence of CKD in children, compared with adults, the cost of treating end- stage renal disease (ESRD) is still significant (42). Total economic cost of North American ESRD programs reached 25.2 billion dollars in 2002 and more increase in the following years was expected (42). Beyond the high prevalence of comorbidities associated with long-term renal replacement therapy, the financial implications are substantial. With an estimated cost of 10,000 EGP per hemodialysis session at our facility, the annual expenditure for a single patient is projected to be 14,00000 Egyptian pound.

Pediatric kidney transplantation (PKT) is the best option for treatment of children with ESRD. Success in areas like the Middle East (ME) remains challenging with unique difficulties regarding care of adults and children with kidney

failure.(43, 44)

Analysis of our study outcomes revealed that While 76% of patients remained under specialized CKD care, the transition from conservative management to transplantation proved challenging for many. While 12.5% remained in the preparatory phase although this process was frequently delayed by issues such as donor accidentally discovered medical issues. Crucially, nearly 19% of the population were unable to complete the transplant work-up, leaving dialysis as the only viable alternative for renal replacement.

Looking to the number of patients who remained actively in need for RRT (213/550) at the end of the study after excluding those group of patients who were in early CKD stages, deaths, lost follow up and those transferred to adult unit care. The study achieved a notable transplantation rate of 18% (38 out of 213 eligible patients for kidney transplantation), this success starkly contrasts with the broader national and international deficit in kidney transplantation. Nationally, despite 92% of Egyptian hemodialysis patients being clinically suitable for surgery, the 2020 Egyptian Renal Data System revealed only 0.3% receive an allograft annually—an incidence of about 3 transplants per 1,000 patient-years, which lags significantly behind the United States' rate of 36 per 1,000 patient-years.(45)

Reviewing the mortality rate among the studied cases was 5%. This was in accordance with study in north America (4% mortality rate among children on hemodialysis) (46), and slightly lower than a similar study Karachi, Pakistan (10%) (47), with nearly the same number of deaths but different sample sizes could explain the difference in the percentage. Our finding were lower than other studies in Egypt (26.7%)(48) and Kingdom of Saudi Arabia (18%).(49) This difference could be explained by the fact that these studies were describing mortality rates among hemodialysis patients only. In our study most deaths occurred in patients on dialysis, accounting for 85.2% (n=23) of all mortalities.

By the end of the study period, we achieved our primary objective of characterizing the local prevalence and burden of pediatric chronic kidney disease (CKD) within our tertiary care setting.

LIMITATIONS

This study has several limitations. First, Egypt lacks a national pediatric CKD registry, and medical documentation across university hospitals is inconsistent, limiting generalizability. Second, as a single center study (n=550), selection bias may be present, although the catchment area covers multiple governorates. Third, whole exome sequencing could not be performed in 101 patients (18.4%) due to financial constraints, potentially underestimating hereditary kidney diseases. Despite these limitations, strengths include the prospective longitudinal design and the rarity of comprehensive pediatric CKD data from low and middle income settings.

CONCLUSION

CAKUT remains the predominant cause of pediatric CKD in this Egyptian cohort, with a large proportion of children presenting at advanced stages of renal failure. To improve outcomes in under resourced regions, we recommend: (1) establishing national pediatric CKD registries, (2) enhancing antenatal and early postnatal screening for CAKUT, (3) increasing access to genetic testing (e.g., WES).

Acknowledgments

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Ethical approval

This study was approved by the Mansoura Faculty of Medicine Institutional Research Board (Approval code; MD.23.02.743).

Author contribution statement

All authors reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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Conflicts of interest
There are no conflicts of interest.

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