Zagazig University Medical Journal
www.zumj.journals.ekb.eg
https://doi.org/10.21608/zumj.2025.401497.4040 Volume 31, Issue 9 September. 2025
Manuscript ZUMJ-2507-4040
DOI: 10.21608/ZUMJ.2025.401497.4040
ORIGINAL ARTICLE

Is There a Difference between Serum Cystatin C and Serum Creatinine Levels Before and After Hemodialysis in Chronic Kidney Disease Children?

Doaa Youssef Mohamed[1], Amal S. El-Shal[2], Mohamed Nabil Ahmed Kelani[1*], Seham Mohamed Ibrahim Ramadan[1]

[1] Pediatrics Department, Faculty of Medicine, Zagazig University, Zagazig, Egypt
[2] Biochemistry Department, Faculty of Medicine, Zagazig University, Zagazig, Egypt

***Corresponding author**

Mohamed Nabil Ahmed Kelani
Pediatrics Department, Faculty of Medicine, Zagazig University, Zagazig, Egypt

Email:
mkelani800@gmail.com

Submit Date 07-07-2025
Revise Date 26-07-2025
Accept Date 05-08-2025

ABSTRACT

Background: Chronic kidney disease (CKD) is a major, prevalent, and serious public health issue, and its prevalence is increasing around the world. Plasma cystatin C (Cys C) is a measure for evaluating kidney function. Its usefulness in assessing whether hemodialysis (HD) is suitable for patients with end-stage renal disease has not been conclusively shown. The study aimed to assess serum Cys C and creatinine (SCr) levels in CKD children pre- and post-HD and to evaluate the effectiveness of serum Cys C determination in cases experiencing low-flux HD.

Methods: This cohort study was performed in the pediatric nephrology unit at Zagazig University Children's Hospitals. All patients of the studied groups were subjected to full history taking, including history of any associated diseases, time of diagnosis and first hemodialysis, frequency of hemodialysis per week, and drug therapy. In addition, a complete physical examination including assessment of general condition, vital signs, and laboratory tests (complete blood picture and serum levels of urea, creatinine, albumin, bilirubin, alanine transaminase (ALT), aspartate aminotransferase (AST), electrolytes, and Cys C).

Results: There was a significant reduction in serum levels of urea and creatinine after hemodialysis as compared to before dialysis. There was statistically significant elevation in Cys C level after dialysis as compared to before dialysis.

Conclusion: Cystatin C is an alternative endogenous marker of kidney function that is unaffected by muscle mass or protein consumption, as well as by sex and age. It rises more rapidly than creatinine, allowing for earlier identification of illness.

Keywords: CKD; Creatinine; Cystatin C; Haemodialysis.

INTRODUCTION

Hemodialysis (HD) effectiveness has a significant impact on end-stage renal disease (ESRD) patients' health and prognosis. To accomplish the greatest possible results, close oversight and follow-up are required. Currently, the efficacy of HD is determined by calculating serum creatinine (SCr) concentrations pre- and post-HD session. Nevertheless, levels of SCr are impacted by variation among individuals associated with age and gender [1].

Cystatin C (Cys C) is an endogenous marker that is unaffected by protein consumption, muscle mass, or physical activity, as well as sex and age. It rises faster than SCr, allowing for earlier identification of illness [2].

All cells contain the small protein Cys C, which is produced steadily and is readily filtered by the glomerulus and has demonstrated the ability to function independently of non-renal stimuli. As a result, serum Cys C is regarded as a reliable substitute indicator of glomerular filtration rate (GFR) [3].

The present work aimed to compare serum Cys C and SCr levels in children with chronic kidney disease (CKD) before and after HD and to evaluate the potential clinical utility of serum Cys C evaluation in HD children.

METHODS

This cohort study was performed at the pediatric nephrology unit at Zagazig University Children's Hospitals. Following Institutional Review Board (ZU-IRB#11108) permission and written informed consent from each patient, the study was conducted. The study was carried out in accordance with the Helsinki Declaration, which is the World Medical Association's code of ethics for human research.

Inclusion criteria

The inclusion criteria of this study were cases with ESRD with age between 3 and 16 years old, arteriovenous fistula created for hemodialysis, and dialysis for at least 3 months.

Exclusion criteria

Cases with the following characteristics were excluded: refusal to participate in the study, patients with thyroid disease or heart disease, and patients on corticosteroid treatment.

History and examination

All patients of the studied groups were subjected to full history taking, including history of any associated diseases, time of diagnosis and first hemodialysis, frequency of hemodialysis per week, and drug therapy. In addition, a complete physical examination was performed, including assessment of general condition, vital signs, and laboratory tests (complete blood picture, serum levels of urea, creatinine, albumin, bilirubin, alanine transaminase (ALT), aspartate aminotransferase (AST), electrolytes, cystatin C, and Kt/V). To assess the efficacy of dialysis, we used serum urea to calculate urea reduction ratio (URR) and blood urea nitrogen (BUN) to calculate Kt/v.

Kt/V Calculation

Kt/V is a standard measure of dialysis adequacy, where K refers to the dialyzer clearance of urea, t is dialysis time, and V is the volume of distribution of urea (total body water). According to accepted clinical guidelines, a Kt/V value ≥1.2 is considered adequate, and >1.4 is optimal. The values observed in this study confirm that most patients received effective dialysis treatment, in agreement with URR results.

$Kt/V = -\ln((BUN\ post / BUN\ pre) - (0.008 \times Hours)) + ((4 - (3.5 \times BUN\ post / BUN\ pre)) \times UFVol / Weight\ post)$.

Where:

BUN pre = Pre-dialysis blood urea nitrogen level

BUN post = Post-dialysis blood urea nitrogen level

Hours = Dialysis session duration in hours

UFVol = Ultrafiltration volume (fluid removed during dialysis) in liters

Weight post = Post-dialysis weight

Sample collection

Before dialysis began, a 5 ml syringe was used for gathering blood samples from the arterial blood port. The post-dialysis blood sample was obtained by pausing ultrafiltration and lowering the blood pump to 100 mL/min for 10 seconds before stopping the pump.

Biochemical analysis

Serum cystatin C was calculated using an ELISA Microplate Reader (Biorad 680) and the two-antibody sandwich ELISA technique. A Spectra scan UV 2600 double beam UV spectrophotometer was used to assess SCr and blood urea. The formula BUN = Blood Urea/2.14 ml was used to calculate BUN.

Statistical analysis

SPSS 24.0 for Windows was used to analyze all of the data. While qualitative data were displayed as numbers and percentages, quantitative data were displayed as mean ± SD, interquartile range, and range. The Chi-square test (X^2) was employed to evaluate categorical variables. The ANOVA test was developed to evaluate multiple groups of normally distributed variables. Shapiro-Wilk and Levine's tests were used to verify the assumptions of normality in each group and variance homogeneity.

For the relation between quantitative variables of two groups, the independent t-test (parametric test) was used for comparison of two independent means and two samples when the variables are quantitative, randomly selected, and normally distributed. The Mann-

Whitney U test (nonparametric test) was used to compare the medians of two populations in order to compare the results of two independent groups. When comparing two or more independent samples that are not normally distributed and have equal or different sample sizes, the Kruskal-Wallis test was employed. For correlation between two quantitative variables, Pearson's correlation was used. Spearman's rank correlation test was used for ordinal data or if the assumptions of normality of data were not satisfied. Logistic regression was employed to determine the relationship between the categorical target variable and one or more independent factors. Data with $P < 0.05$ was considered significant.

RESULTS

This study included 45 CKD children on regular hemodialysis (low-flux dialyzers), with a mean age of 12.24 years. Females represented 51.1% of cases. The mean weight, height, and body mass index (BMI) were 30.76 kg, 120.69 cm, and 20.76 kg/m^2, respectively. The mean systolic and diastolic blood pressure (SBP and DBP) were 132.44 and 81 mmHg, respectively. Disease duration ranged from 0.3 to 12 years with a median of 4 years (Table 1).

The mean hemoglobin, white blood cells (WBCs), and platelet counts were 10.03 g/l, 10.15 (10^3/mm^3) and 279.84 (10^3/mm^3), respectively. The mean albumin level was 3.92 g/dL. The mean total and direct bilirubin levels were 0.982 and 0.296 mg/dl, respectively. The mean total calcium, phosphorus, sodium, and potassium were 9.06, 3.16, 145.4, and 4.84 mg/dl, respectively. The mean urea reduction ratio (URR) was 67.84, and the median C-reactive protein (CRP) was 1 mg/L. Percent reduction in serum creatinine ranged from 16.28 to 88.14% with a median of 54.9%, where all patients had a reduction in creatinine. The median percent change in serum cystatin C was 10.53%, where 66.7% of patients had an increase in cystatin C and 31.1% had a decrease in cystatin C post-HD. The mean Kt/V value was 1.35 ± 0.19, indicating adequate dialysis in most patients, with a range from 1.04 to 1.68 (Table 2).

The majority of the participants in the research showed an increase in serum cystatin C after hemodialysis. This happened despite the concurrent decrease in serum creatinine, which is a well-regarded indicator of dialysis adequacy. The derived values, creatinine reduction ratio (CRR) and cystatin C reduction ratio (CYRR), showed the divergent behavior of the two molecules toward the process of HD (Tables 2 & 3, Figure 1).

There was a statistically highly significant reduction in serum urea and creatinine after hemodialysis as compared to before dialysis level. There was a statistically significant increase in serum cystatin C after hemodialysis as compared to before dialysis level. The two parameters studied to evaluate the efficacy of HD, namely SCr and serum Cys C, showed conflicting results (Table 3). There was a significant positive association between pre-HD Cys C and pre-HD SCr ($r=0.993$, $p<0.001$), but there was a non-significant correlation between post-HD Cys C and post-HD Cr ($r=0.152$, $p = 0.320$).

A statistically significant positive correlation was observed only between urea reduction ratio (URR) and Kt/V ($r = 0.893$, $p < 0.001$), indicating that higher URR values are strongly associated with increased Kt/V. No other correlations among the variables reached statistical significance ($p > 0.05$) (Table 4).

There was a statistically significant negative correlation between URR and both direct and total bilirubin. There was also a statistically significant negative correlation between CRR and serum phosphorus. There was a statistically non-significant correlation between URR, CYRR, CRR and age, clinical and other laboratory parameters (Table 5).

Among the various clinical and laboratory parameters examined, a statistically significant negative correlation was observed between Kt/V and direct bilirubin levels ($r = –0.240$, $p = 0.022$), with no statistically significant difference between Kt/V and age, clinical and other laboratory parameters (Table 6).

Table (1): Distribution of studied patients according to demographic and disease-specific data

Variables	N (Total = 45)	%
Demographic data		
Sex		
• **Female**	23	51.1%
• **Male**	22	48.9%
	Mean ± SD	**Range**
Age (year)	12.24 ± 3.12	6 – 16
Weight (kg)	30.76 ± 12.28	15 – 58
Height (cm)	120.69 ± 19.24	80 – 160
BMI (kg/m^2)	20.76 ± 5.53	12.97 – 32.45
Systolic blood pressure (mmHg)	132.44 ± 9.51	100 – 150
Diastolic blood pressure (mmHg)	81.0 ± 7.58	60 – 95
Disease-specific data		
	N	**%**
Cause		
• **CAKUT**	17	37.8%
• **Glomerulopathy**	9	20%
• **Systemic**	11	24.4%
• **Unknown**	8	17.8%
Medications		
• **Metoprolol Succinate**	18	40%
• **Captopril**	4	8.9%
• **Methyldopa**	3	6.7%
• **Carvedilol**	1	2.2%
• **Propranolol**	1	2.2%
	Median (IQR)	**Range**
Disease duration (year)	4 (2 – 6)	0.3 – 12

BMI, Body Mass Index; CAKUT, Congenital anomalies of kidney and urinary tract.

Table (2): Distribution of studied patients according to laboratory data

Variables	Mean ± SD	Range
Hemoglobin (g/dl)	10.03 ± 0.87	8.4 – 11.4
WBCs (10^3/mm^3)	10.15 ± 3.34	4.6 – 19.2
Platelet count (10^3/mm^3)	279.84 ± 85.67	149 – 420
Albumin (g/dl)	3.92 ± 0.85	2.6 – 5.5
Total bilirubin (mg/dl)	0.982 ± 0.363	0.6 – 2.2
Direct bilirubin (mg/l)	0.296 ± 0.095	0.2 – 0.5
Total calcium (mg/dl)	9.06 ± 0.9	6.8 – 10.9
Phosphorus (mg/dl)	3.16 ± 1.21	1.8 – 6.1
Sodium (mg/dl)	145.4 ± 8.18	122 – 161
Potassium (mg/dl)	4.84 ± 0.73	3.1 – 6.8
URR	67.84 ± 7.12	54.44 – 86.51
Kt/V	1.35 ± 0.19	1.04 – 1.68
CRP (mg/L)	1(0.7 – 6)	0.3 – 12
Creatinine percent reduction	54.9(45.33% - 69.81%)	16.28 – 88.14%
Cystatin C percent change	10.53(-7.28% - 41.94%)	-83.92 – 599.07%
CYRR	-10.53(-41.94, 7.28%)	-599.07, 83.92%
	N=45	**%**
Cystatin C		
• **Reduction**	14	31.1%
• **No change**	1	2.2%
• **Increase**	30	66.7%
Creatinine Reduction	45	100%

CRP; C-reactive protein; CYRR, Cystatin C Reduction Ratio; Kt/V, Dialysis Dose Indicator; URR, Urea Reduction Ratio; WBCs, White Blood Cells.

Table (3)**:** Changes in serum urea, creatinine and cystatin C before and after hemodialysis

Variables	Before	After	t	*P*-value
Urea (mg/dl) • **Mean ± SD** • **Range**	102.11 ± 12.58 80 – 129	32.4 ± 6.6 17 – 49	32.915	<0.001**
Creatinine (mg/dl) • **Mean ± SD** • **Range**	7.12 ± 2.07 4 – 11	3.04 ± 1.33 0.7 – 5.5	14.932	<0.001**
Cystatin C (mg/L) • **Median (IQR)** • **Range**	4.5 (3.61 – 6.25) 2.94 – 24.3	4.97 (4.21 – 9.39) 2.91 – 24.6	Wx = -2.001	0.045*

t: Paired sample t-test
Wx: Wilcoxon signed rank test
** p<0.05 is statistically significant*
*** p≤0.001 is statistically highly significant*

IQR, Interquartile Range; SD, Standard Deviation.

Table (4): Correlation between URR, CRR and CYRR among studied patients

	URR		CRR		CYRR		Kt/V	
	r	***P*-value**	**r**	***P*-value**	**r**	***P*-value**	**r**	***P*-value**
URR			-0.055	0.719	0.028	0.856	**0.893**	**<0.001****
CRR	-0.055	0.719			0.021	0.891	-0.104	0.495
CYRR	0.028	0.856	0.021	0.891			0.006	0.967

r: Spearman Correlation Coefficient
*** p≤0.001 is statistically highly significant*

CRR, Creatinine Reduction Ratio; CYRR, Cystatin C Reduction Ratio; KTV, Dialysis Dose Indicator;; URR: Urea Reduction Ratio.

Table (5): Correlation between URR, CYRP,CRR, and the studied parameters

	URR		CYRP		CRR	
	r	***P*-value**	**r**	***P*-value**	**r**	***P*-value**
Age (year)	0.083	0.589	0.201	0.187	-0.15	0.325
Weight (kg)	0.065	0.673	0.017	0.913	-0.083	0.589
Height (cm)	0.048	0.752	-0.06	0.695	-0.103	0.5
BMI (kg/m^2)	-0.031	0.839	0.043	0.778	0.037	0.808
SBP (mmHg)	-0.044	0.774	-0.137	0.368	0.054	0.726
DBP (mmHg)	-0.068	0.658	-0.08	0.601	0.012	0.937
Disease duration (year)	0.164	0.283	0.135	0.377	-0.117	0.444
Hemoglobin (g/dl)	-0.181	0.234	-0.063	0.682	0.131	0.391
WBCs (10^3/mm^3)	-0.016	0.919	-0.227	0.134	-0.116	0.484
Platelet count (10^3/mm^3)	0.014	0.926	0.179	0.238	-0.084	0.581
Albumin (g/dl)	0.105	0.494	-0.228	0.131	-0.271	0.072
Total bilirubin (mg/dl)	**-0.472**	**<0.001****	0.103	0.502	-0.056	0.717
Direct bilirubin (mg/l)	**-0.489**	**<0.001****	0.148	0.332	-0.077	0.615
Total calcium (mg/dl)	0.135	0.378	-0.03	0.845	-0.084	0.581
Phosphorus (mg/dl)	-0.022	0.887	0.075	0.626	**-0.342**	**0.022***
Sodium (mg/dl)	-0.24	0.113	0.015	0.923	-0.195	0.2

	URR		CYRP		CRR	
	r	***P*-value**	**r**	***P*-value**	**r**	***P*-value**
Potassium (mg/dl)	-0.023	0.88	-0.252	0.095	-0.04	0.793
CRP (mg/L)	-0.128	0.402	-0.16	0.295	0.171	0.26

r: Spearman rank correlation coefficient
** p<0.05 is statistically significant*
*** p≤0.001 is statistically highly significant*

BMI, Body Mass Index; CRP, C-reactive protein; CRR, Creatinine Reduction Ratio; CYRR, Cystatin C Reduction Ratio; DBP, Diastolic blood pressure; SBP, Systolic blood pressure; URR, Urea Reduction Ratio; WBCs, White Blood Cells.

Table (6): Correlation between Kt/V and the studied parameters

	Kt/V	
	r	***P*-value**
Age (year)	0.208	0.169
Weight (kg)	0.146	0.337
Height (cm)	0.099	0.516
BMI (kg/m^2)	0.103	0.503
Systolic blood pressure (mmHg)	0.045	0.769
Diastolic blood pressure (mmHg)	0.037	0.811
Disease duration (year)	0.217	0.152
Hemoglobin (g/dl)	-0.1	0.514
WBCs (10^3/mm^3)	-0.002	0.99
Platelet count (10^3/mm^3)	0.108	0.48
Albumin (g/dl)	0.154	0.312
Total bilirubin (mg/dl)	-0.262	0.082
Direct bilirubin (mg/l)	**-0.24**	**0.022***
Total calcium (mg/dl)	0.029	0.849
Phosphorus (mg/dl)	0.049	0.748
Sodium (mg/dl)	-0.282	0.061
Potassium (mg/dl)	-0.057	0.71
CRP (mg/L)	0.001	0.998

r: Spearman rank correlation coefficient
*** P<0.05 is statistically significant*
BMI, Body Mass Index; CRP, C-reactive protein; Kt/V, Dialysis Dose Indicator; WBCs, White Blood Cells.

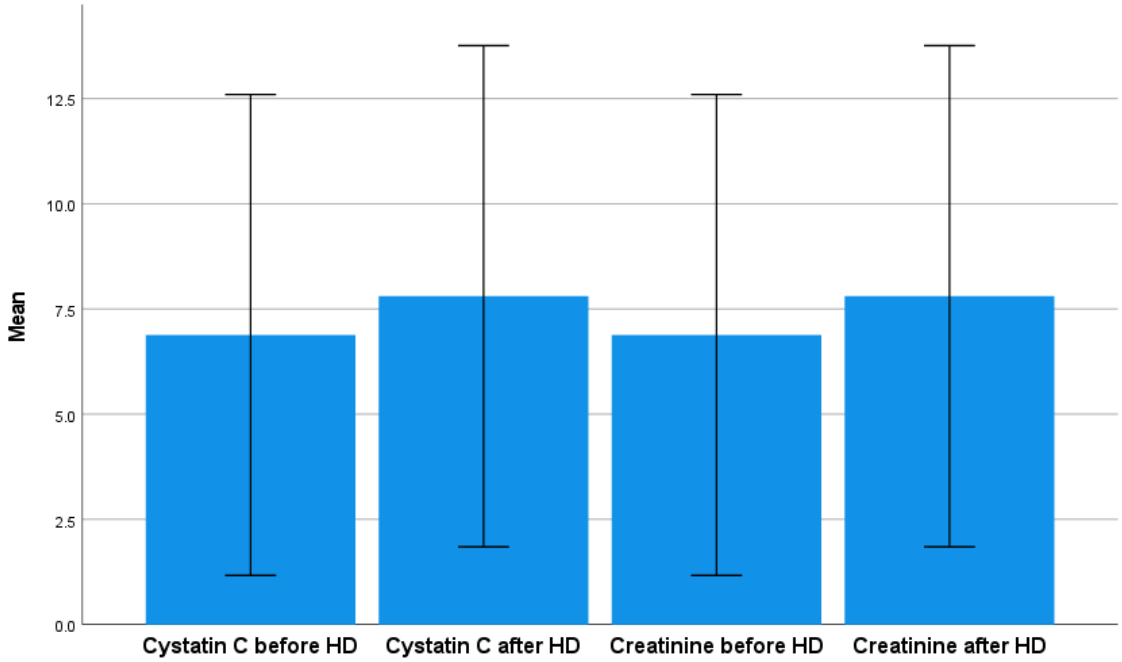

Figure (1): Bar chart showing serum cystatin and creatinine levels before and after hemodialysis.

DISCUSSION

The efficacy of HD has a substantial influence on the health, survival, and outcome of ESRD cases. As a consequence, rigorous evaluation and follow-up are required to achieve optimal findings. The efficiency of dialysis is currently assessed by monitoring the creatinine level in the blood before and after each session. Nevertheless, individual variation in SCr concentrations is influenced by sex and age [4].

Cys C is an alternative endogenous marker that is unaffected by muscle mass or protein consumption, as well as by sex and age. It rises more rapidly than creatinine, allowing for earlier identification of illness [5].

Our study included 45 children aged 6 to 16 years with CKD. The demographic data showed an almost equal distribution of male and female participants, with 51.1% females and 48.9% males. This gender distribution aligns with the general pediatric CKD population, where no significant gender predisposition is typically observed [6].

The mean BMI of 20.76 kg/m^2 indicates that these children had a wide range of body mass indices (range: 12.97–32.45), reflecting the diverse nutritional statuses often seen in CKD patients [7].

In our study, the mean SBP and DBP were 132.44 mmHg and 81.0 mmHg, respectively. Hypertension is a common finding in pediatric CKD due to fluid overload and increased peripheral resistance [8].

In our study, the mean hemoglobin level was 10.03 g/dl, indicating mild anemia, a common complication in CKD due to erythropoietin deficiency [9]. Amanullah et al. [10] revealed an anemic incidence of 81% in the late CKD cohort compared to 33% in the initial CKD group. According to NAPRTCs, the rate of anemia was 73% at stage 3 CKD, 87% at stage 4, and above 93% at stage 5 [11].

The mean albumin level was 3.92 g/dl, reflecting potential hypoalbuminemia commonly associated with liver diseases, reduced nutritional intake due to anorexia secondary to uremic toxins, comorbid illnesses such as cardiovascular diseases and renal and GIT losses of protein [12].

Our study found a significant reduction in serum urea and creatinine levels post-hemodialysis. Serum urea was reduced from 102.11 ± 12.58 mg/dl to 32.4 ± 6.6 mg/dl (p <

0.001). SCr was reduced from 7.12 ± 2.07 mg/dl to 3.04 ± 1.33 mg/dl ($p < 0.001$). Our study detected a remarkable increase in serum Cys C values post-HD, increasing from 4.5 (3.61 – 6.25) mg/L to 4.97 (4.21 – 9.39) mg/L ($p = 0.045$).

Our study reported a median creatinine reduction ratio (CRR) of 54.9% and a median cystatin C reduction ratio (CYRR) of 9.52%. While all patients showed a reduction in creatinine, only 31.1% showed a reduction in cystatin C, with 66.7% experiencing an increase.

Throughout our study, we utilized a diacetate hollow fiber dialyzer, a low-flux HD. The increase in Cys C during HD could be related to a variety of reasons, including the type of the HD membrane and the content of the HD fluid. When low-flux HD is employed, protein removal such as Cys C is hindered.

Lindström et al. [13] assumed that Cystatin C removal was likewise found to be restricted by low-flux hemodialysis. They reported that hemodiafiltration and hemofiltration reduced cystatin C levels ($p < 0.001$). This agrees with Al-Malki et al. [14] and Huang et al. [15], who reported that high-flux HD reduces Cys C post-HD.

This agrees with Hawale et al. [16], who reported that, before hemodialysis, the levels of serum creatinine were substantially higher, but after hemodialysis, they were substantially lower ($P < 0.0001$). S Cys C levels increased considerably after HD compared to before ($P < 0.0001$).

Kutum et al. [17] revealed that the pre-dialysis group's SCr concentrations were significantly higher than those of the control group ($p<0.0001$). After HD, SCr concentrations were significantly lower than in the pre-HD group ($p < 0.0001$).

Since muscle mass affects the excretion of Cr, which is almost entirely produced in the muscle, urine excretion is the most reliable indicator of muscle mass [18].

Hojs et al. [19] showed that serum Cys C has a higher accuracy in diagnosis than Cr and is a helpful indicator of GFR for people with mild to moderate renal function issues.

Furthermore, a strong positive correlation was found between URR and Kt/V ($r = 0.893$, $p < 0.001$), underscoring the consistency of these two widely used measures of dialysis adequacy. This observation is in agreement with Al-Malki et al. [14] and Huang et al. [15], who reported similar findings in adult HD populations, supporting the interchangeable utility of both markers in clinical practice. In contrast, no significant correlations were observed between URR, CRR, or CYRR, which may be explained by the limited clearance of middle molecules like cystatin C in low-flux dialysis, as previously noted by Lindström et al. [13].

Several investigations have assumed that the serum Cys C level may be superior to SCr in identifying normal and pathological GFR [20].

In our study, no significant correlations were found between URR, CRR, CYRR, and other clinical parameters such as age, BMI, blood pressure, and disease duration. These findings underscore the complexity of CKD and the multifactorial influences on dialysis outcomes.

Hoek et al. [21] demonstrated that Cys C levels before HD were substantially linked with mean SCr ($r = 0.505$; $P < 0.001$).

Recent research has demonstrated that factors other than renal function, such as CRP and smoking status, may influence Cys C readings; hence, care must be used when evaluating serum Cys C levels as a measure of renal function [22].

The presence of Cys C in urine during glomerular and tubular damage casts some question on the applicability of serum Cys C to reliably assess GFR [23].

Wang et al. [24] assumed that Cys C has been linked to a variety of adiposity measurements. They identified a substantial relationship between BMI and smoking with serum Cys C levels, with a favorable correlation found exclusively among non-smokers but not among smokers.

A common reference interval of 0.61-1.01 mg/L was developed since a Danish study indicated no sex-related differences in the

reference ranges for plasma Cys C in males (0.62-1.04 mg/L) and females (0.58-1.00 mg/L) [25].

In our study, no statistically significant differences were observed in URR, CRR, or CYRR between male and female patients, suggesting that gender does not influence the effectiveness of hemodialysis in removing urea, creatinine, or cystatin C.

This aligns with previous studies that also found no significant gender differences in dialysis outcomes [26]. Wang et al. [24] observed that cystatin C had a less strong association with sex than creatinine. A Danish study established reference intervals for plasma Cys C in women (0.58–1.00 mg/L) and men (0.62–1.04 mg/L) and revealed no sex-related differences; therefore, a common reference interval of 0.61–1.01 mg/L was suggested [25].

Ziegelasch et al. [27] found Cys C values vary with age, sex, and height, especially throughout puberty and infancy. They suggested employing age- and sex-specific reference values for serum Cys C values to estimate renal function in clinical practice.

In our study, a statistically significant negative correlation was observed between Kt/V and direct bilirubin levels ($r = –0.240$, $p = 0.022$), suggesting that higher dialysis adequacy may be associated with reduced bilirubin concentrations in pediatric CKD patients. This finding aligns with the results reported by Kabanda et al. [28], who demonstrated enhanced dialysis efficiency, particularly when high-flux membranes were used, and this was associated with lower levels of several low molecular weight proteins and toxins, including bilirubin fractions. Similarly, in their analysis of hemodialysis patients, Al-Malki et al. [14] noted that increasing dialysis dose correlated inversely with markers of hepatic congestion, including bilirubin, further reinforcing the link between systemic toxin removal and hepatic biochemical markers.

Conversely, our findings contrast with the study by Lindström et al. [13], who reported no significant association between Kt/V and bilirubin levels in patients undergoing both conventional and high-efficiency dialysis modalities. They attributed this lack of correlation to the multifactorial nature of bilirubin metabolism, which can be influenced by comorbid hepatic dysfunction, hemolysis, and medication use. These factors may mask any direct impact of dialysis clearance. In our pediatric population, however, these confounders were likely less prominent or better controlled, which might explain the emergence of a statistically significant association.

CONCLUSION

In contrast to creatinine, post-dialysis Cys C levels are markedly elevated. Thus, Cys C can't be utilized to assess dialysis efficiency. Nevertheless, it functions as an alternative sign of the insufficiency of low-flow HD in removing low molecular weight proteins from the circulation.

Conflict of interest: None.

Financial disclosures: None.

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Citation

Mohamed, D., El-Shal, A., Ahmed Kelani, M., Ibrahim Ramadan, S. Is There Difference Between Serum Cystatin C and Serum Creatinine Levels Before and After Hemodialysis in Chronic Kidney Disease Children. *Zagazig University Medical Journal*, 2025; (4572-4581): -. doi: 10.21608/zumj.2025.401497.4040