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Contribution of Cystatin C to the Estimation of Glomerular Filtration Rate in Patients with End-Stage Renal Disease Undergoing Hemodialysis at the Souro Sanou Teaching Hospital in Bobo-Dioulasso (Burkina Faso)

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Abstract

Introduction: Glomerular filtration rate (GFR) is calculated to estimate renal function. Classically, the formulae used to calculate it include creatinine, which is a marker influenced physiologically by age, sex, muscle mass and race. Given these difficulties, cystatin C (cystC), a protein that is freely filtered by the glomerulus, has emerged as a promising biomarker of renal function. The main objective of this study was to investigate the contribution of cystatin C to GFR estimation in patients with end-stage renal disease (ESRD) undergoing hemodialysis at the SS-TH of Bobo-Dioulasso in Burkina Faso. **Material and Methods:** This was a prospective study of CKD hemodialysis patients recruited at the SS-TH from 1 January 2022 to 28 February 2022. Socio-demographic data were obtained after review of the medical records of hemodialysis patients with ESRD. All biochemical parameters were measured on the COBAS® 6000 automated system. Colorimetric methods were used to measure urea, creatinine and albumin. CRP, alpha-1-glycoprotein acid and transthyretin were determined by the immunoturbidimetric method. The GFRs were calculated using the calculator on the website of the Société Francophone de Néphrologie, Dialyse et Transplantation. **Discussion:** A total of 39 hemodialysis patients with CKD were included in the study. The mean age was 43.87 ± 11.75 years. There was a male predominance with a sex ratio (M/F) of 1.56. Mean serum cystC was 7.38 ± 1.66 g/L. A positive and significant correlation was observed between cystC and markers such as albuminemia (r = 0.574, p = 0.0001) and

transthyretinemia (r = 0.572, p = 0.0001). The CKD-EPI-Creat-CystC formula was more accurate in identifying 100% of patients in stage 5 (GFR < 15 ml/min/1.73m^2), unlike the other formulas (Cockcroft and Gault, MDRD, CKD-EPI-Creat, CKD-EPI-CystC). The mean GFR values of the CKD-EPI-Creat and CKD-EPI-Creat-CystC formulae were significantly higher in male patients. Hypertensive patients had mean GFR values obtained by the CKD-EPI-Creat-CystC formula that were significantly higher than those of patients without hypertension (5.72 ± 2.30 mL/min/1.73m^2 vs 4.16 ± 0.75 mL/min/1.73m^2, p-value = 0.004). **Conclusion:** Estimation of GFR using the CKD-EPI-Creat-CystC formula would contribute to accurate diagnosis of the clinical stage of chronic kidney disease and could predict cardiovascular risk in CKD patients undergoing hemodialysis.

Keywords

Cystatin C, Creatinine, Glomerular Filtration Rate, End-Stage Renal Disease, Burkina Faso

1. Introduction

Chronic kidney disease (CKD) is a major global public health problem [1] and mortality is increasing [2]. A study carried out in Burkina Faso in the town of Bobo-Dioulasso showed that acute renal failure resulted in a mortality rate of 10.1% [3]. Severe chronic renal failure resulted in a mortality rate of 47.7% during hospitalisation at the Souro Sanou University Hospital (CHUSS) [4]. In view of this high prevalence, early and accurate identification of the clinical stage by estimating glomerular filtration rate (GFR) is a prerequisite for better management of patients with kidney failure. Traditional methods use formulas for estimating GFR that include creatinine, which is a marker physiologically influenced by age, sex, muscle mass and race. In the face of these difficulties, cystatin C, a protein freely filtered by the glomerulus, has emerged as a promising biomarker of renal function.

Cystatin C is a small protein consisting of 120 residues forming a single polypeptide chain [5]. It belongs to the family of type 2 cysteine proteinase inhibitors [5]. Cysteine proteinases irreversibly hydrolyse a peptide bond in an amino acid sequence and play an important role in cell regulation, cell proliferation and adhesion, apoptosis, lipid metabolism and immune response [5]. It is widely distributed and found in most body fluids, including plasma [6]. Its interest in assessing renal function stems from its physical and chemical properties as an endogenous marker. In addition, due to its constant production, it is relatively freely filtered by glomeruli, is reabsorbed and catabolised by proximal renal tubular cells and is not affected by muscle mass [7], unlike creatinine [8]. Despite its great value in diagnosing kidney damage, some authors have shown that laboratory tests for cystatin C cost around 10 times more than creatinine, which limits its use in routine practice [7]. Further-

more, cystatin C could also have other advantages in a resource-limited setting through the prediction of coronary artery disease independently of its role in estimating renal function [9]-[11]. In Burkina Faso, there are few studies on cystatin C in GFR estimation [12]. With this in mind, we conducted the present study to assess the contribution of cystatin C to GFR estimation in patients with end-stage chronic kidney disease undergoing haemodialysis at the Bobo-Dioulasso CHUSS in Burkina Faso.

2. Patients and Methods

2.1. Type and Study Site

This was a cross-sectional analytical study, with data collection taking place over a two-month period from 1 January 2022 to 28 February 2022. The study population consisted of end-stage CKD patients followed in the nephrology-dialysis department and who had undergone their biological work-up in the laboratory department of the Souro Sanou Teaching Hospital (SS-TH) in Bobo-Dioulasso, Burkina Faso. The study included end-stage CKD patients with stage 5 hemodialysis who were aged over 18 years. Our sampling was exhaustive, taking into account those who agreed to participate in the study and also the availability of our reagents.

2.2. Data Analysis and Processing

Blood samples were taken at the time of their dialysis session. The blood sample was immediately transported to the laboratory and centrifuged at 3500 rpm for 5 minutes for analysis. Biochemical marker assays were performed after calibration and internal quality control in accordance with the biochemistry laboratory's internal procedures.

Colorimetric methods were used on the Roche systems Cobas® 6000 multiparameter system (Roche/Hitachi) to measure urea (urease/Glutamate dehydrogenase), albumin (bromocresol blue) and creatinine (modified Jaffé). CRP, alpha 1 glucoprotein, transthyretin and cystatin C were measured by immunoturbidimetric methods. Serum creatinine assays using the enzymatic method (creatininase/sarcosine oxidase-peroxidase) were performed on the INDIKO Plus® (ThermoFisher©).

The study variables concerned socio-demographic aspects such as age, sex, area of residence, occupation, body mass index (BMI), date of start of dialysis and pathological history. The biological variables we investigated were uremia, creatininaemia, CRP, albumin, alpha-1-glycoprotein acid and cystatin C, as well as glomerular filtration rates (GFRs) obtained using the Cockcroft & Gault, MDRD (Modified Diet Renal Diseases), CKD-EPI (Chronic Kidney Disease-Epidemiology Collaboration) clearance equations using creatinine and cystatin C.

Calculations of the different glomerular filtration rates were carried out as part of this study using the calculator available on the website of the French-speaking Society of Nephrology, Dialysis and Transplantation (SFNDT) [13] [14].

The equations used were:

- Cockcroft and Gault equation

in men = 1.23 × Weight (kg) × (140 − age)/creatinine (µmol/l).

in women = 1.04 × Weight (kg) × (140 − age)/creatinine (µmol/l).

- Modification of Diet in Renal Disease (MDRD) Study equation Simplified version (in men) = 186 × (creatinine (µmol/l) × 0.0113) − 1.154 × age − 0.203 × 1.21 for subjects of African origin (African American) × 0.742 for women.
- GFR equation was estimated using the CKD-EPI (Chronic Kidney Disease-Epidemiology Collaboration) formula.

African subject

In women > 62 µmol/L, GFR = 166 × (creatin/0.7) − 1.209 × (0.993) (age). In men > 80 µmol/L, GFR = 163 × (creatin/0.9) − 1.209 × (0.993) (age).

- Equation for GFR estimated using the CKD-EPI formula, Cystatin C, in ml/min/1.73m^2.

Serum cystatin C > 0.8 mg/L.

$133 \times (Scys/0.8)^{-1.328} \times 0.996^{Age}$ [×0.932 if female].

- GFR estimated by the mixed formula CKD-EPI creatinine-Cystatin C, in ml/min/1.73m^2.

Female creatinemia > 62 µmol/L Serum cystatin C > 0.8 mg/L.

$130 \times (Scr/62)^{-0.601} \times (Scys/0.8)^{-0.711} \times 0.995^{Age}$ [×1.08 if of African origin]. Men creatinine > 80 µmol/L.

Serum cystatin C > 0.8 mg/L.

$135 \times (Scr/80)^{-0.601} \times (Scys/0.8)^{-0.711} \times 0.995^{Age}$ [×1.08 if African origin] (if African origin).

Before the start of the study, a request for authorisation to collect data was obtained from the management of the SS-TH. Data confidentiality was maintained throughout the study.

Data were collected using Excel 2016 and statistical analyses were performed using R software version 3.6.1. Means (m) and standard deviations (SD) were calculated for quantitative variables such as age and concentrations of biochemical parameters. Student's t-test was used to compare means. The Pearson correlation coefficient was used to determine the association of cystatin C with the variables studied. A probability of less than 0.05 was considered significant for all variables.

3. Results

In total, our study included 39 patients with CKD undergoing haemodialysis at the SS-TH, whose duration of dialysis ranged from 3 months to 49 months.

3.1. Socio-Demographic Characteristics

Table 1 describes the socio-demographic characteristics of the study population. The mean age of the patients was 43.87 ± 11.75 years, with extremes ranging from 22 to 72 years. Males predominated, with a sex ratio (M/F) of 1.56. All patients were dialysed with an average of 2 dialysis sessions per week. The mean duration of dialysis was 2.44 ± 1.04 years, and 46.15% of patients had been on dialysis for

≥3 years.

Table 1. Socio-demographic characteristics of patients.

Features	Parameters	Patients (N = 39)
Age	Average age (m ± TE), (years)	43.87 ± 11.75
Gender	Male, n (%)	24 (61.54)
	Female, n (%)	15 (38.46)
Area of residence	Urban, n (%)	35 (89.74)
	Rural, n (%)	4 (10.26)
Profession	Employees, n (%)	14 (35.9)
	Non-employees, n (%)	25 (64.1)
Pathological history	HTA, n (%)	33 (84.62)
	Vascular nephropathy, n (%)	20 (51.28)
	Cardiac pathology, n (%)	5 (12.82)
Dialysis time	Average duration (m ± ET), (years)	2.44 ± 1.04
	Duration < 3 years, n (%)	21 (53.85)
	Duration ≥ 3 years, n (%)	18 (46.15)
BMI	Average BMI (m ± SD), (kg/m^2)	20.74 ± 2.92
	BMI ≤ 23 (kg/m^2), n (%)	34 (87.18)
	BMI > 23 (kg/m^2), n (%)	5 (12.82)

In terms of anthropometric parameters, the mean BMI of patients was 20.74 ± 2.92 kg/m^2. A breakdown of haemodialysis patients by BMI bracket revealed that 87.18% were malnourished (BMI ≤ 23 kg/m^2). Pathological history showed hypertension in 84.62% of patients, 51.28% had vascular nephropathy and 12.82% had cardiac pathology.

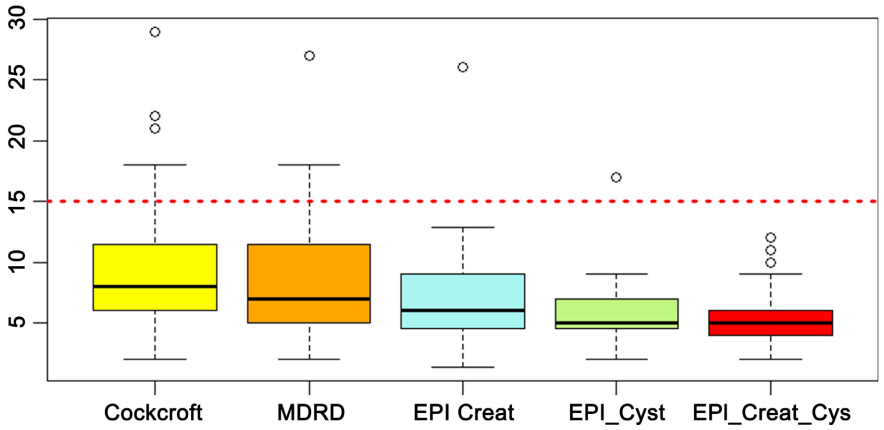

Figure 1. GFR estimates for CKD patients using the 5 GFR calculation formulas.

Figure 1 presents the GFR estimates in patients with CKD using the five GFR

calculation formulas. It shows that the combined CKD-EPI-Creat-CystC formula was more accurate in clinically determining patients at stage 5 than the other formulas.

3.2. Mean Values of Biochemical Markers in Haemodialysis Patients with CKD

The mean values of anthropometric parameters, biochemical markers and estimated glomerular filtration rates assessed during the study are presented in Table 2.

Table 2. Mean values of parameters in CKD hemodialysis patients.

Parameters	Values (m ± ET)
Anthropometric variables	
Average weights (kg)	60.60 ± 9.54
Average height (m)	1.71 ± 0.07
Average BMI (kg/m^2)	20.74 ± 2.92
Biochemical markers	
CRP, (mg/L)	1.98 ± 1.27
Haptoglobulin, (g/L)	1.07 ± 0.65
Alpha-1 glucoprotein acid, (g/L)	1.08 ± 0.29
Albumin, (g/L)	42.96 ± 4.72
Transthyretin, (g/L)	0.46 ± 0.13
Urea, (mmol/L)	13.43 ± 5.29
Enzymatic creatinine, (µmol/L)	869.92 ± 390.75
Cystatin C, (mg/L)	7.38 ± 1.66
Estimation of glomerular filtration rate	
Cockcroft & gault clearance, (mL/min)	9.41 ± 5.53
MDRD, (ml/min/1.73m^2)	8.41 ± 4.78
GFR-CKD-EPI-Creat, (ml/min/1.73m^2)	7.17 ± 4.34
GFR-CKD-EPI-CystC, (ml/min/1.73m^2)	5.79 ± 2.46
GFR-CKD-EPI-Creat-CystC, (ml/min/1.73m^2)	5.49 ± 2.21

GFR by MDRD: Glomerular filtration rate by Modified Diet Renal Disease (ml/min/1.73m^2).

3.3. Correlation between Cystatin C and the Parameters Studied

Table 3 shows the correlation between Cystatin C and anthropometric parameters, biochemical markers and estimated values of glomerular filtration rates assessed during the study. Indeed, a significant positive correlation was observed between cyclstatin and markers such as albumin and transthyretin. Similarly, a negative but significant correlation was also observed between GFR-CKD-EPI-CystC and GFR-CKD-EPI-Creat-CystC with cystatin in our study.

Table 3. Correlation between cystatin C and the parameters studied.

Parameters	r	t	95% confidence interval		p-value
			Min	Max	
Anthropometric variables and ages					
Age of patients, (years)	0.100	0.614	−0.222	0.403	0.542
Number of years on dialysis, (years)	0.299	1.907	−0.017	0.561	0.064
Weight, (kg)	−0.224	−1.398	−0.503	0.098	0.170
Size, (m)	−0.038	−0.234	−0.349	−0.280	0.815
BMI, (kg/m^2)	−0.234	−1.465	−0.511	0.087	0.151
Biochemical markers					
CRP, (mg/L)	−0.125	−0.769	−0.424	0.197	0.446
Haptoglobulin, (g/L)	0.245	1.543	−0.075	0.521	0.131
Alpha-1 glucoprotein acid, (g/L)	0.212	1.325	−0.109	0.495	0.193
Albumin, (g/L)	0.574	4.268	0.316	0.753	0.0001*
Transthyretin, (g/L)	0.572	4.245	0.313	0.752	0.0001*
Urea	−0.210	−1.31	−0.493	0.112	0.198
Modified Jaffe creatinine	−0.138	−0.853	−0.435	0.184	0.398
Enzymatic creatinine	−0.134	−0.827	−0.431	0.188	0.413
Estimation of glomerular filtration rate					
Clairance Cockcroft & Gault	−0.082	−0.503	−0.387	0.239	0.617
MDRD	0.013	0.082	−0.303	0.327	0.934
DFG-CKD-EPI-Creat	−0.162	−1	−0.454	0.161	0.323
DFG-CKD-EPI-CystC	−0.829	−9.029	−0.907	−0.695	0.000*
DFG-CKD-EPI-Creat-CystC	−0.470	−3.240	−0.684	−0.181	**0.002***

*p < 0.05.

3.4. Factors Associated with Variations in Formulae for Estimating Renal Function

Table 4 describes the variations in renal function markers as a function of factors such as age, duration of dialysis, BMI and the patient's pathological history.

Table 4. Variation in renal function markers according to sociodemographic and clinical factors.

Features	Workforce	Urea (m ± ET), (mmol/L)	Creat_Enzy (m ± ET), (µmol/L)	Cystatin C (m ± ET), (mg/L)
Gender				
Male	24 (61.54)	12.37 ± 4.63	794.08 ± 317.53	7.32 ± 1.76
Female	15 (38.46)	15.12 ± 5.98	991.26 ± 472.38	7.47 ± 1.53
Dialysis time				
Duration < 3 years	21 (53.85)	13.72 ± 4.66	789.85 ± 247.13	7.03 ± 1.69
Duration ≥ 3 years	18 (46.15)	13.08 ± 6.06	963.33 ± 502.28	7.78 ± 1.56

Continued

BMI					
BMI ≤ 23 (kg/m²)		34 (87.18)	13.71 ± 5.57	909.26 ± 399.55	7.48 ± 1.73
BMI > 23 (kg/m²)		05 (12.82)	11.48 ± 2.01	602.40 ± 175.68	6.70 ± 0.87
Pathological history					
Vascular nephropathy		20 (51.28)	12.47 ± 12.47	805.60 ± 311.53	7.29 ± 1.28
Cardiac pathology		5 (12.82)	14.22 ± 4.21	1015.0 ± 338.99	7.41 ± 1.20
HTA	Yes	33 (84.41)	12.79 ± 4.93	847.93 ± 409.88	7.22 ± 1.59
	No	06 (15.39)	16.95 ± 6.27	990.83 ± 253.91	8.24 ± 1.91

Table 5 shows the variations in the calculation of glomerular filtration rate according to the factors mentioned above. In this table, the glomerular filtration rate estimation formulas incorporating creatinine were significantly higher in male subjects. In addition, patients with associated arterial hypertension had significantly higher mean filtration rate estimates using the formula incorporating creatinine and cystatin C, compared to subjects without hypertension.

Table 5. Factors associated with variations in glomerular filtration rate.

Features		Workforce, n (%)	CKD-EPI Creat (m ± ET)	p-value	CKD EPI Cyst (m ± ET)	p-value	CKD EPI Creat Cyst (m ± ET)	p-value
Gender								
Male		24 (61.54)	8.29 ± 4.86		6.00 ± 2.78		6.20 ± 2.37	
Female		15 (38.46)	5.35 ± 2.54	0.018*	5.46 ± 1.88	0.480	4.33 ± 1.29	0.002*
Dialysis time								
Duration < 3 years		21 (53.85)	7.31 ± 3.09	0.833	6.38 ± 2.99	0.095	5.85 ± 2.28	0.261
Duration ≥ 3 years		21 (53.85)	6.99 ± 5.54		5.11 ± 1.45		5.05 ± 2.09	
BMI								
BMI ≤ 23(kg/m²)		34 (87.18)	6.74 ± 4.35	0.088	5.64 ± 2.53	0.248	5.29 ± 2.23	0.116
BMI > 23 (kg/m²)		05 (12.82)	10.03 ± 3.25		6.80 ± 1.78		6.80 ± 1.64	
Pathological history								
Vascular nephropathy		20 (51.28)	7.97 ± 4.86	0.234	6.00 ± 2.97	0.596	5.95 ± 2.48	0.180
Cardiac pathology		5 (12.82)	5.47 ± 3.09	0.260	6.00 ± 2.34	0.843	4.60 ± 2.07	0.353
HTA	Yes	33 (84.41)	7.46 ± 4.59		5.93 ± 2.59		5.72 ± 2.30	
	No	6 (15.39)	5.51 ± 2.04	0.110	5.00 ± 1.41	0.223	4.16 ± 0.75	0.004*

*p < 0.05.

4. Discussion

The primary objective of this study was to evaluate the contribution of cystatin C to estimating GFR in patients with end-stage renal disease (ESRD) undergoing hemo-

dialysis at the SS-TH in Bobo-Dioulasso, Burkina Faso. The main limitation of the study is the sample size obtained, which does not allow extrapolation of the results to the entire population of ESRD patients undergoing hemodialysis. Similarly, our limited reagent resources and the cross-sectional nature of the study could lead to various biases (selection and confounding factors). Despite these limitations, one of the strengths of this study is that it enabled the study of useful biomarkers with predictive value for kidney damage and cardiovascular risk.

Cystatin C is a low molecular weight protein of approximately 13 kDa that is constantly produced by all nucleated cells, filtered freely in the glomerulus and metabolised in the proximal tubule [15]. Its metabolism in humans appears to be characterised by constant synthesis independent of nycthemeral variations, significant glomerular filtration and total renal elimination in the proximal tubules. These aspects explain the interest in measuring it in renal disorders. Traditionally, creatinine has been the most widely used marker in laboratories for assessing renal function, because it is easier to measure (Jaffé and enzymatic method) than cystatin C. A study conducted by the General Chemistry Survey 2019 of the College of American Pathologists indicated that only 7% of US clinical laboratories offered cystatin C tests and that more than 90% of them referred the tests to external commercial laboratories [16]. In Burkina Faso, cystatin C does not appear to be widely tested in medical laboratories. A single study by Da *et al.* on the prevalence of chronic kidney disease in retired people in the town of Bobo-Dioulasso used a GFR calculation based on cystatin C [12].

Given the limitations of creatinine measurement, particularly because of its influence on muscle mass, cystatin C measurement offers several advantages. Our study showed no significant correlation between serum cystatin C and anthropometric parameters (weight, height and BMI), patient age, number of years on dialysis and traditional markers of renal function (urea, enzymatic creatinine and Jaffet) in end-stage CKD patients on dialysis. In fact, several studies have shown that cystatin C is little influenced by factors such as muscle mass, age, sex and diet, making it a much more advantageous biomarker than creatinine for investigating renal function [17] [18].

In our study, a positive and significant correlation was observed between cystatin C and markers such as serum albumin ($r = 0.574$, $p = 0.0001$) and transthyretin ($r = 0.572$, $p = 0.0001$). These results suggest that serum albumin and transthyretin concentrations increased at the same time as serum cystatin C concentrations increased. This could be explained by the possible complications of end-stage renal disease under dialysis, where renal clearance is reduced, leading to retention of serum proteins such as albumin, transthyretin and cystatin C.

In our study, a negative and significant correlation was observed between cystatin C and DFG-CKD-EPI-CystC values obtained using cystatin C ($r = -0.829$, p-value = 0.000) and that coupling cystatin C and serum creatinine ($r = -0.470$, p-value = 0.002). These data suggest that a fall in GFR-CKD-EPI-CystC and GFR-CKD-EPI-Creat-CystC values is associated with an increase in serum cystatin C

concentrations. Thus, the measurement of cystatin C and its inclusion in the DFG-CKD-EPI formulae alone or combined with creatinine are consistent with the fact that cystatin C is an indicator of the deterioration of renal function. Indeed, several authors have shown that patients with advanced CKD (G3 - G5) have higher serum cystatin C than patients with milder CKD (G1 - G2) [16] [19].

From the oldest equations, such as Cockcroft & Gault, through MDRD, to the most recent with the Chronic Kidney Disease Epidemiology Consortium (CKD-EPI), the choice of eGFR equation is often not straightforward for the black African population. Indeed, these equations are often obtained on the basis of epidemiological surveys that do not report sufficient data for black subjects due to the lower representation of blacks in European countries. However, scientific societies such as the European Federation of Clinical Chemistry and Laboratory Medicine maintain their support for the CKD-EPI 2009 equation and also recommend increased use of cystatin C due to its independence from race, aiming for more accurate estimates of GFR in various populations [20] [21]. Black subjects tend to have higher muscle mass than Caucasians [22]. Creatinine, being the muscle breakdown product of creatine, is likely to be underestimated in Caucasian subjects [22].

The 2009 CKD-EPI creatinine equation includes gender, age, creatinine and race [14] [23]. On the other hand, the 2021 CKD-EPI creatinine equation includes age, sex and creatinine, but excludes race [23] [24]. As a result, to avoid over- or underestimating GFRs, several scientific societies are tending to use the CKD-EPI equations published in 2012, which take into account cystatin C alone and in combination with creatinine [14] [25].

In our study, all patients had end-stage hemodialysis and were clinically classified as stage 5 CKD. The mixed CKD-EPI formula showed 100% of patients in stage 5 (GFR < 15 ml/min/1.73m^2), whereas the other two, which took creatinine and cystatin C alone into account, excluded one patient outside this stage. The mixed CKD-EPI formula therefore appeared to be more accurate than that using creatinine and cystatin C alone. The same observation was made by several authors, for whom the bias with the combined creatinine-cystatin C formula was lower than with equations taking creatinine and cystatin C alone into account [18] [24]. The combined formula was therefore more accurate and resulted in a more precise classification of GFR measured as less than 60 ml/min/1.73m^2 [18] [24].

Overall, this mixed CKD-EPI-Creat-CystC formula is tending to be proposed by several scientific societies for its accuracy in confirming the diagnosis and classification of CKD, despite the associated costs. One study shows that the cystatin C test costs around 10 times more than the creatinine test, which limits its use in routine practice [8].

Our study shows that haemodialysis CKD patients with hypertension had significantly higher mean GFR-CKD-EPI values combining creatinine and cystatin C compared with patients without hypertension (CKD-EPI-Creat-CystC with hypertension = 5.72 ± 2.30 mL/min/1.73m^2 vs CKD-EPI-Creat-CystC without hyperten-

sion = 4.16 ± 0.75 mL/min/1.73m^2, p-value = 0.004). This increase in mixed CKD-EPI in hypertensive patients could be explained by a pronounced deterioration in renal function and blood pressure regulation. For example, some authors described that serum cystatin C levels in patients with uncontrolled hypertension were higher than those in patients with controlled hypertension and no hypertension, although all groups had normal serum creatinine concentrations [26]. These data suggest that the increase in cystatin C associated with uncontrolled hypertension may be manifestations of renal microvascular damage [26]-[29]. In addition, several studies have shown that cGFR and eGFRcys-creat below 85 mL/min/1.73m^2 were associated with an increased risk of death from any cause and cardiovascular disease [8] [30]-[32].

5. Conclusion

In our study of end-stage renal disease patients on haemodialysis, we found that serum cystatin C concentrations correlated with those of biomarkers such as albumin and transthyretin. For estimating GFR, the combined creatinine-cystatin C formula was more accurate in diagnosing the clinical stage and led to a more precise classification of GFR in chronic kidney disease. Also, the mean values of CKD-EPI combining creatinine and cystatin C were significantly elevated in patients with hypertension, suggesting its value in predicting cardiovascular risk.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Webster, A.C., Nagler, E.V., Morton, R.L. and Masson, P. (2017) Chronic Kidney Disease. *The Lancet*, **389**, 1238-1252. https://doi.org/10.1016/s0140-6736(16)32064-5

[2] De Nicola, L. and Minutolo, R. (2016) Worldwide Growing Epidemic of CKD: Fact or Fiction? *Kidney International*, **90**, 482-484. https://doi.org/10.1016/j.kint.2016.05.001

[3] Ouédraogo, P.V., Ouédraogo, R.L.A., Diendéré, J., Bagbila, W.P.A.H., Sagna, Y. and Millogo, A. (2022) Aspects épidémiologiques, cliniques et facteurs pronostiques des accidents vasculaires cérébraux ischémiques chez le sujet âgé à Bobo-Dioulasso, Burkina Faso. *Annales Africaines de Medecine*, **15**, e4589-e4595. https://doi.org/10.4314/aamed.v15i2.7

[4] Aoua, S., *et al.* (2023) Epidemiology, Clinical Presentation and Outcome of Acute Kidney Injury in the City of Bobo-Dioulasso (Burkina Faso). *Health Sciences and Disease*, **24**, 114-118.

[5] Shamsi, A. and Bano, B. (2017) Journey of Cystatins from Being Mere Thiol Protease Inhibitors to at Heart of Many Pathological Conditions. *International Journal of Biological Macromolecules*, **102**, 674-693. https://doi.org/10.1016/j.ijbiomac.2017.04.071

[6] Grubb, A.O. (2001) Cystatin C-Properties and Use as Diagnostic Marker. In: *Advances in Clinical Chemistry*, Elsevier, 63-99. https://doi.org/10.1016/s0065-2423(01)35015-1

[7] Inker, L.A. and Titan, S. (2021) Measurement and Estimation of GFR for Use in Clinical Practice: Core Curriculum 2021. *American Journal of Kidney Diseases*, **78**, 736-749. https://doi.org/10.1053/j.ajkd.2021.04.016

[8] Spencer, S., Desborough, R. and Bhandari, S. (2023) Should Cystatin C eGFR Become Routine Clinical Practice? *Biomolecules*, **13**, Article No. 1075. https://doi.org/10.3390/biom13071075

[9] Dandana, A., Gammoudi, I., Chahed, H., Ferchichi, S., Maatouk, F. and Miled, A. (2012) Intérêt du dosage de la cystatine C chez des patients coronariens tunisiens. *Immuno-Analyse & Biologie Spécialisée*, **27**, 20-27. https://doi.org/10.1016/j.immbio.2011.10.005

[10] Ge, J., Ji, Y., Wang, F., Zhou, X., Wei, J. and Qi, C. (2023) Correlation between Cystatin C and the Severity of Cardiac Dysfunction in Patients with Systolic Heart Failure. *Risk Management and Healthcare Policy*, **16**, 2419-2426. https://doi.org/10.2147/rmhp.s437678

[11] Ma, J., Bian, S. and Gao, M. (2023) Prediction of Outcomes through Cystatin C and cTnI in Elderly Type 2 Myocardial Infarction Patients. *Clinical Interventions in Aging*, **18**, 1415-1422. https://doi.org/10.2147/cia.s416372

[12] Da, O., Semde, A., Some, A.F., Zongo, E., Kabore, N.F., Sanou, D., *et al.* (2020) Prévalence de la Maladie Rénale Chronique chez les personnes retraitées dans la ville de Bo-bo-Dioulasso (Burkina Faso). *Science et Technique*, *Sciences de La Santé*, **43**, 81-89.

[13] Société Francophone de Néphrologie, Dialyse et Transplantation (SFNDT) (n.d.) MDRDs-CKD-EPI-Cockcroft. https://www.sfndt.org/professionnels/calculateurs/calculateur-DFG

[14] Inker, L.A., Schmid, C.H., Tighiouart, H., Eckfeldt, J.H., Feldman, H.I., Greene, T., *et al.* (2012) Estimating Glomerular Filtration Rate from Serum Creatinine and Cystatin C. *New England Journal of Medicine*, **367**, 20-29. https://doi.org/10.1056/nejmoa1114248

[15] Grubb, A., Simonsen, O., Sturfelt, G., Truedsson, L. and Thysell, H. (1985) Serum Concentration of Cystatin C, Factor D and β2-Microglobulin as a Measure of Glomerular Filtration Rate. *Acta Medica Scandinavica*, **218**, 499-503. https://doi.org/10.1111/j.0954-6820.1985.tb08880.x

[16] Chen, D.C., Potok, O.A., Rifkin, D. and Estrella, M.M. (2022) Advantages, Limitations, and Clinical Considerations in Using Cystatin C to Estimate GFR. *Kidney*360, **3**, 1807-

1814. https://doi.org/10.34067/kid.0003202022

[17] Skidmore, M., Spencer, S., Desborough, R., Kent, D. and Bhandari, S. (2024) Cystatin C as a Marker of Kidney Function in Children. *Biomolecules*, **14**, Article No. 938. https://doi.org/10.3390/biom14080938

[18] Visinescu, A., Rusu, E., Cosoreanu, A. and Radulian, G. (2024) CYSTATIN C—A Monitoring Perspective of Chronic Kidney Disease in Patients with Diabetes. *International Journal of Molecular Sciences*, **25**, Article No. 8135. https://doi.org/10.3390/ijms25158135

[19] Serge, N.M., Philippe, C.M., Olivier, M.K., Christian, K.N., Cédrick, S.M., Pascal, N.T., *et al.* (2017) Maladie rénale chronique: Facteurs associés, étiologies, caractéristiques clinique et biologique à Lubumbashi en République Démocratique du Congo. *Pan African Medical Journal*, **28**, Article No. 41. https://doi.org/10.11604/pamj.2017.28.41.9810

[20] Delanaye, P., Schaeffner, E., Cozzolino, M., Langlois, M., Plebani, M., Ozben, T., *et al.* (2022) The New, Race-Free, Chronic Kidney Disease Epidemiology Consortium (CKD-EPI) Equation to Estimate Glomerular Filtration Rate: Is It Applicable in Europe? A Position Statement by the European Federation of Clinical Chemistry and Laboratory Medicine (EFLM). *Clinical Chemistry and Laboratory Medicine* (*CCLM*), **61**, 44-47. https://doi.org/10.1515/cclm-2022-0928

[21] Wang, Y., Adingwupu, O.M., Shlipak, M.G., Doria, A., Estrella, M.M., Froissart, M., *et al.* (2023) Discordance between Creatinine-Based and Cystatin C-Based Estimated GFR: Interpretation According to Performance Compared to Measured GFR. *Kidney Medicine*, **5**, Article ID: 100710. https://doi.org/10.1016/j.xkme.2023.100710

[22] Chaba, L., Scoffier-Mériaux, S., Lentillon-Kaestner, V. and d'Arripe-Longueville, F. (2018) Recherche de prise de masse musculaire et dysmorphie musculaire chez les bodybuilders: Une revue de la littérature anglophone. *Staps*, **119**, 65-79. https://doi.org/10.3917/sta.119.0065

[23] Stevens, P.E., Ahmed, S.B., Carrero, J.J., Foster, B., Francis, A., Hall, R.K., *et al.* (2024) KDIGO 2024 Clinical Practice Guideline for the Evaluation and Management of Chronic Kidney Disease. *Kidney International*, **105**, S117-S314. https://doi.org/10.1016/j.kint.2023.10.018

[24] Inker, L.A., Eneanya, N.D., Coresh, J., Tighiouart, H., Wang, D., Sang, Y., *et al.* (2021) New Creatinine- and Cystatin C-Based Equations to Estimate GFR without Race. *New England Journal of Medicine*, **385**, 1737-1749. https://doi.org/10.1056/nejmoa2102953

[25] Benoit, S.W., Ciccia, E.A. and Devarajan, P. (2020) Cystatin C as a Biomarker of Chronic Kidney Disease: Latest Developments. *Expert Review of Molecular Diagnostics*, **20**, 1019-1026. https://doi.org/10.1080/14737159.2020.1768849

[26] Omaygenç, M.O., Özcan, Ö.U., Çakal, B. and Karaca, O. (2020) Cystatin C and Uncontrolled Hypertension. *The Anatolian Journal of Cardiology*, **24**, 309-315. https://doi.org/10.14744/anatoljcardiol.2020.78974

[27] Peralta, C.A., Whooley, M.A., Ix, J.H. and Shlipak, M.G. (2006) Kidney Function and Systolic Blood Pressure New Insights from Cystatin C: Data from the Heart and Soul Study. *American Journal of Hypertension*, **19**, 939-946. https://doi.org/10.1016/j.amjhyper.2006.02.007

[28] Shankar, A. and Teppala, S. (2011) Relationship between Serum Cystatin C and Hypertension among US Adults without Clinically Recognized Chronic Kidney Disease. *Journal of the American Society of Hypertension*, **5**, 378-384. https://doi.org/10.1016/j.jash.2011.03.003

[29] Otsuka, T., Kato, K., Kachi, Y., Ibuki, C., Seino, Y., Kodani, E., *et al.* (2013) Serum Cystatin C, Creatinine-Based Estimated Glomerular Filtration Rate, and the Risk of Incident Hypertension in Middle-Aged Men. *American Journal of Hypertension*, **27**, 596-602. https://doi.org/10.1093/ajh/hpt164

[30] Lasserson, D.S., Shine, B., O'Callaghan, C.A. and James, T. (2017) Requirement for Cystatin C Testing in Chronic Kidney Disease: A Retrospective Population-Based Study. *British Journal of General Practice*, **67**, e732-e735. https://doi.org/10.3399/bjgp17x692585

[31] Shlipak, M.G., Matsushita, K., Ärnlöv, J., Inker, L.A., Katz, R., Polkinghorne, K.R., *et al.* (2013) Cystatin C versus Creatinine in Determining Risk Based on Kidney Function. *New England Journal of Medicine*, **369**, 932-943. https://doi.org/10.1056/nejmoa1214234

[32] Shlipak, M.G., Mattes, M.D. and Peralta, C.A. (2013) Update on Cystatin C: Incorporation into Clinical Practice. *American Journal of Kidney Diseases*, **62**, 595-603. https://doi.org/10.1053/j.ajkd.2013.03.027