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Glomerular filtration formulas to assess clinical and neuropsychological status in geriatric patients with chronic heart failure: a comparison of three formulas

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ABSTRACT

Introduction: Impaired renal function is a common problem among elderly patients with chronic heart failure. It is related to prognosis and treatment. The most proper assessment of glomerular filtration in this population seems to be crucial, but despite technological advances, it is still relatively difficult. This study aimed to find the best glomerular filtration formula in the group of geriatric patients with chronic heart failure, which would correlate with their clinical and psychological status.

Material and methods: The study was conducted in a group of 101 hospitalized patients aged over 60 with stable chronic heart failure. All patients were subjected to clinical and psychological evaluation. Obtained data were compared with the estimated glomerular filtration rate calculated by three equations (Cockcroft-Gault with adjustment for body surface area, Modification of Diet in Renal Disease, and Chronic Kidney Disease Epidemiology).

Results: For all 3 formulas, statistically significant correlations were found between renal function and age, the New York Heart Association functional class, a period of hospitalization, N-terminal-pro-B-type natriuretic peptide, and a 6-minute walk test score. The widest range of values was found for the Cockcroft-Gault formula with adjustment for body surface area. The Cockcroft-Gault formula with adjustment for body surface area showed also strong associations with cognitive functioning.

Conclusions: Renal function calculated by the Cockcroft-Gault formula with adjustment for body surface area highly correlates with psychological parameters among geriatric patients with congestive heart failure (CHF).

Key words: chronic heart failure, cognitive functioning, eGFR, geriatric patients, glomerular filtration

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Introduction

Congestive heart failure (CHF) is defined as a clinical syndrome characterized by typical symptoms (e.g. breathlessness, fatigue, lower limbs swelling) caused by a structural and/or functional cardiac abnormality, resulting in elevated intracardiac pressures (at rest or during stress) or a reduced cardiac output [1]. The prevalence of CHF is about 1–2% of the adult population in developed countries and more than 10% of patients over 70 years of age [1]. It is emphasized that CHF is associated with reduced quality of life, more frequent hospitalizations, as well as increased mortality compared to healthy people [2, 3]. CHF is related to diseases such

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as stroke [4], vascular dementia, Alzheimer's disease [5], depression, and anxiety [6, 7] and is a recognized risk factor for cognitive impairment [2]. It is estimated that from 30% to even 80% of patients with CHF are diagnosed with abnormalities in neuropsychological tests depending on the performed tests, the severity of the disease, and the age of the examined person [2, 8]. The risk factors for decompensating the disease include non-compliance with pharmacotherapy, restrictions on fluid intake, and failure to recognize early signs of exacerbation of heart failure. Notably, it may be also associated with co-existing cognitive impairment [2].

Another clinically important problem among geriatric patients is impaired renal function. The decline of glomerular filtration is a sign of a decreasing number of nephrons and a worsening of kidney function. It reduces 0.3 to 1 mL/min/1.73m^2/year among people without proteinuria or comorbidity and is approximately two to three times higher among patients with proteinuria or comorbidity [12]. It has further implications – the retention of toxins, related to a deterioration of kidney function, can also affect the emergence of the brain and cognitive dysfunctions [13, 14].

The most precise methods assessing the excretory function of the kidney are glomerular filtration rates (GFR). GFR is an amount of plasma filtered out in all glomeruli per unit of time. Glomerular filtration can be measured, for example, with inulin clearance or the isotopic method, or estimated (eGFR) using many formulas [for example, Modification of Diet in Renal Disease 4-variable version (MDRD4) or Chronic Kidney Disease Epidemiology (CKD-EPI)] [12]. A Cockroft and Gault formula estimates creatinine clearance and not glomerular filtration; it has been developed to predict creatinine from serum creatinine in adult males [12, 15]. The kidney function is also demonstrated by other factors such as the presence and intensity of albuminuria but also by the secretory or metabolic function. Despite semantic differences, in this work, expressions eGFR and renal function are used interchangeably.

The Cockcroft-Gault formula with adjustment for body surface area (CG-BSA), MDRD4, and CKD-EPI formulas are based on a level of serum creatinine in milligrams per deciliter and differing personal and anthropometric parameters, such as age, sex, or race (Tab. 1). None of these three basic methods is perfect. They try to assess eGFR, but all of them have limitations. CG-BSA equation inflates creatinine clearance in obese and over-hydrated persons and decreases it in lean and older subjects [16, 17]. This may have major implications for assessment in geriatric populations with CHF because age or residual fluid retention may affect body weight.

Co-existing diseases can influence each other, and exacerbation of one can cause decompensation of the other. Similarly, taking medications prescribed for one disease may adversely affect other diseases. This is the case, for example, in CHF and chronic kidney disease, which frequently coincide. They both can affect the brain and cognitive functions. Moreover, renal function is independently associated with cardiological prognosis and treatment [9–11]. That is why geriatric diagnostics and therapeutics are multifaceted, multi-disease processes and thus represent a considerable challenge for physicians.

Considering the kidney's role in maintaining the homeostasis of the organism, the most proper assessment of renal function in geriatric patients with CHF seems to be crucial, but despite technological advances, it is still relatively demanding. Such a method should be simple, available, and cost-efficient.

Therefore, this study aimed to determine which of the above-mentioned methods of eGFR assessment in this population reveals the strongest correlations with clinical and cognitive parameters.

Material and methods

The study cohort comprised 101 patients (28 females and 73 males) with CHF hospitalized for different reasons at the University Hospital No. 2 in Bydgoszcz in 2017 after stabilizing their general condition. All patients were Polish, Caucasian, and > 60 years of age. The mean age of the cohort was 75.0 years (range 60–97). The following inclusion criteria were adopted: (1) chronic heart failure diagnosed according to the European Society of Cardiology guidelines [1], based on medical history, medical examination, electrocardiogram, N-terminal pro B-type natriuretic peptide (NT-proBNP), and echocardiography (ECHO), (2) ability to perform a six-minute walking test, (4) ability to understand the purpose of the examination, (5) lack of incapacitation, and (6) the patient's informed consent to participate in the study. The exclusion criteria were serious somatic, psychiatric, or neurological disorders and lack of ability to perform a walking test. All participants were informed about the aims of this study and gave their written informed consent. Permission for the study was obtained from the Bioethical Commission of the Nicolaus Copernicus University, *Collegium Medicum* in Bydgoszcz (No. KB 48/2017), and the study conformed to recognized standards of the Declaration of Helsinki.

After medical stabilization (which was confirmed by the lack of peripheral edema and the absence of typical auscultatory changes in a physical examination of the chest), when the patient has reached its typical weight, he or she underwent clinical and neuropsychological assessment. The clinical evaluation comprised an analysis of medical history, a comprehensive physical examination, measurement of weight and height, an evaluation of physical fitness, echocardiographic examination, and blood analysis. Physical fitness was assessed via the 6-minute walk test (6MWT) [20]. ECHO was performed using the Toshiba Aplio 300 by the same experienced echocardiographer. The evaluation included the following elements: the left atrium, the left ventricular diastolic diameter, the left ventricular posterior wall diameter, the left ventricular ejection fraction, and the interventricular septal diastolic diameter. Blood analysis included NT-pro BNP and creatinine levels (performed using enzymatic methods). The assessment of renal function was based on 3 formulas: MDRD4 ($eGFR_{MDRD4}$), CKD-EPI ($eGFR_{CKD\text{-}EPI}$), and CG-BSA ($CrCl_{CG\text{-}BSA}$) (Tab. 1) [12]. Although the analysis of relevance between renal function parameters calculated according to different patterns was statistically significant, mutual correlations of results counted with all three methods, the widest range values of glomerular filtration assessment were found for the CG-BSA formula (Tab. 1). It covers both the maximum and the minimum of results.

The presence and severity of depression and anxiety symptoms were assessed using the Hospital Anxiety and Depression Scale (HADS). Cognitive function was assessed using the computer-based test battery (Neurotest), which comprises the following [22]:

— Simple reaction time test (SRT): to evaluate the speed and correctness of simple reactions to stimuli. The patient's task is to respond to the stimulus in the form of a green circle appearing on the computer screen. The participant is instructed to respond as quickly as possible. The actual test is preceded by a trial version in which the stimulus is presented five times. The number of correct answers and the average response time are measured. The SRT task measures response time, general vigilance, and psychomotor speed.
— Verbal memory test (VM): to determine the efficiency of the working memory (VM1), short-term memory (VM2, VM3, VM4, and VM5), and deferred memory (verbal memory deferred test; VMDT). It is a complex task. The first part consists of five stages. The researcher reads the list of the same ten words 5 times. The examined person has to recall the words after each reading, remembering the story in any order. To assess the test result, the researcher records for each test: the number of correctly repeated words, the number of intrusions (words outside the list), and the number of perseverations (repetitions). Part 2 takes place after 20 minutes and relies on a list of reminders by the tested words from the previous list, however, this time the researcher does not read the words aloud. The test evaluates immediate auditory memory (number of words saved), learning (improvement of results in subsequent repetitions), and deferred memory (remembering repeating words).
— GoNoGo test: to assess the response time under the conditions of the need to trigger cognitive control and cognitive inhibition. It consists of two reactions, marked as "Go" and "NoGo." The "Go" part requires the participant to press the key when a green square appears on the computer screen. The "NoGo" concerns the lack of reaction (not pressing the key) when a blue square appears on the screen. The stimuli are presented randomly. The

Table 1. Various formulas for estimating the glomerular filtration rate and eGFR results in the study group measured by different methods

Various formulas for estimating the glomerular filtration rate and its results in the study group		**Median**	**Min**	**Max**	**Q25**	**Q75**
$CrCl_{CG\text{-}BSA}$ ($eGFR_{CG\text{-}BSA}$), mL/min	= 1.73m^2 × { [(140-age in years) × body weight in kg × 0.85 (if female)]/(72 × serum creatinine in mg/dL)} / BSA	50.8	14.5	126.4	41.6	65.9
$eGFR_{MDRD4}$, mL/min/1.73m^2	= 175 × (serum creatinine in mg/dL)$^{-1.154}$ × age in years$^{-0.203}$ × 0.742 (if female) × 1.212 (if black)	54.7	20.1	104.3	41.2	68.8
$eGFR_{CKD\text{-}EPI}$, mL/min/1.73m^2	= 141 × min [(serum creatinine in mg/dL)/κ,1]α × max [(serum creatinine in mg/dL)/κ,1]$^{-1.209}$ × 0.993$^{\text{age in years}}$ × 1.018 (if female) × 1.159 (if black)	63.0	19.0	120.0	44.0	75.0
eGFR r-Spearman's correlations	$eGFR_{CG\text{-}BSA}$ and $eGFR_{MDRD4}$ r = 0.678; p < 0.00001	$eGFR_{CG\text{-}BSA}$ and $eGFR_{CKD\text{-}EPI}$ r = 0.699; p < 0.00001		$eGFR_{CKD\text{-}EPI}$ and $eGFR_{MDRD4}$ r = 0.911; p < 0000.1		

BSA is (height in cm × weight in kg/3600)$^{0.5}$, κ is 0.7 for females and 0.9 for males, α is –0.329 for females and –0.411 for males, min indicates the minimum of serum creatinine/κ or 1, max indicates the maximum of serum creatinine/κ or 1.

Data are presented as medians, minimum and maximum values and as 1st and 4th quartiles.

$CrCl_{CG\text{-}BSA}$ — creatinine clearance calculated by the Cockroft-Gold method adjusted by body surface area; eGFR — estimated glomerular filtration rate; $eGFR_{CG\text{-}BSA}$ — eGFR calculated by the Cockroft-Gold method adjusted by body surface area; $eGFR_{CKD\text{-}EPI}$ — eGFR calculated by the Chronic Kidney Disease Epidemiology Collaboration; $eGFR_{MDRD4}$ — eGFR calculated by Modification of Diet in Renal Disease 4-variable version time (ms) of correct "Go" reactions and the number and percentage of correct and incorrect "Go" and "NoGo" reactions are examined.

Statistica 13 was used to conduct statistical analyses. A Shapiro-Wilk test revealed that the distribution of variables was not normal; therefore, nonparametric tests were used: the Mann-Whitney U test to assess the statistical significance of the differences and the Spearman rank correlation test to determine correlations between variables. Furthermore, the Cohen's d effect size was used to facilitate comparisons across results.

Results

The demographic, anthropometric, and clinical characteristics of the cohort are shown in Table 2.

Correlations between glomerular filtration assessment and clinical parameters are shown in Table 3**.** For all 3 formulas, statistically significant correlations were found between higher glomerular filtration and (I) lower age; (II) a shorter period of hospitalization; (III) the NT-pro BNP serum level, and (IV) a superior 6MWT score. The CG-BSA test showed statistically significant positive correlations with almost all cognitive test results. Higher CG-BSA was associated with shorter reaction times in the SRT and GoNoGo tests and with a higher number of remembered words in all attempts in the VM test of words recalled and in the VMDT. When the group was divided into patients with eGFR above and below 45ml/min according to CG-BSA, it turned out that in the group with higher eGFR significantly better results were obtained for the VM1, VM2, and VM3 trials in the word memory test, in the deferred memory test, and the distance in the 6MWT (Tab. 4). The CKD-EPI test was associated with superior SRT and GoNoGo reaction times and a higher number of remembered words in some VM attempts. However, the significance level was lower than for CG-BSA. No correlations with cognitive test results were found for the MDRD4 formula. The groups of patients with eGFR > 45 mL/min according to CKD-EPI and MDRD4 were characterized only by significantly higher results in the 6MWT.

Table 2. Demographic, clinical, and neuropsychological data in the study group

Parameter		**Study group**
Age [years]		75 (66–81)
Duration of hospitalization [days]		5,0 (4–8)
BMI [kg/m^2]		29.7 (25.6–34.1)
DM, n		49 (48.5%)
HA, n		79 (78%)
AF, n		51 (50.5%)
IHD, n		57 (56.5%)
NYHA	II, n	69
	III, n	32
ECHO	LVEF, %	43.0 (32.5–55.0)
	IVSd [mm]	1.2 (1.1–1.4)
	LVDd [mm]	5.4 (4.9–6.9)
	LVPWd [mm]	1.2 (1.0–1.3)
	LA [mm]	5.0 (4.5–5.3)
NT-pro BNP [mU/L]		2552.0 (13730–5017.0)
eGFR, mL/min	Cockcroft–Gault BSA	51.8 (42.8–69.5)
	MDRD4	49.2 (39.8–66.1)
	CKD-EPI	50.5 (44.0–70.0)
HADS A		6.0 (4.0–8.0)
HADS D		6.0 (3.0–8.0)
6MWT [m]		188.0 (145.0–265.0)
SRT correct answers, n		25.0 (25.0–25.0)
SRT reaction time [ms]		439.4 (290.5–676.9)
VM1, n		4.0 (3.0–5.0)
VM2, n		5.0 (4.0–6.0)
VM3, n		6.0 (5.0–7.0)
VM4, n		6.0 (5.0–8.0)
VM5, n		6.0 (5.0–8.0)
VMDT, n		4.0 (3.0–6.0)
GnG incorrect NoGo, n		6.0 (3.0–9.0)
GnG correct Go, n		72.0 (66.0–74.0)
GnG reaction time [ms]		394.5 (342.9–471.6)

Data are presented as medians and 25th and 75th quartiles or in the number of subjects (n).

6MWT — six minutes walking test; AF — atrial fibrillation; BMI — body mass index; DM — diabetes mellitus; ECHO — echocardiography; GnG — GoNoGo test; HA — arterial hypertension; HADS A/D — Hospital Anxiety and Depression Scale: Anxiety/Depression; IHD — ischemic heart disease; IVSd — interventricular septal diastolic diameter; LA — left atrium; LVDd — left ventricular diastolic diameter; LVEF — left ventricular ejection fraction; LVPWd — left ventricular posterior wall diameter; NT-proBNP — N-terminal pro b-type natriuretic peptide; NYHA — the New York Heart Association; SRT — simple reaction test; VM 1–5 — verbal memory: trials 1, 2, 3, 4, 5; VMDT — verbal memory delayed test

Discussion

Value of three formulas in assessing the glomerular filtration in terms of clinical status in geriatric patients with CHF

This study did not reveal significant differences in the value of these three formulas in terms of indicating the clinical status of geriatric subjects with CHF. It was

Table 3. Spearman's rank correlation coefficient of eGFR calculated with different methods with clinical, echocardiographic, and neuropsychological factors

	Cockcroft-Gault BSA	MDRD4	CKD-EPI
Age	r = –0.5; p < 0.0000001	r = –0.2; p = 0.02	r = –0.3; p = 0.0005
BMI	r = 0.2; p = 0.07	r = –0.2; p = 0.09	r = –0.2; p = 0.09
Duration of hospitalization	r = –0.3; p = 0.001	r = –0.3; p = 0.002	r = –0.2; p = 0.01
NT-proBNP	r = –0.3; p = 0.001	r = –0.4; p = 0.0006	r = –0.3; p = 0.002
LVEF	r = 0.03; p = 0.7	r = 0.1; p = 0.2	r = 0.03; p = 0.8
LVDd	r = 0.09; p = 0.4	r = –0.05; p = 0.6	r = –0.01; p = 0.9
LA	r = –0.04; p = 0.7	r = –0.1; p = 0.1	r = –0.08; p = 0.4
6MWT	r = 0.3; p = 0.004	r = 0.2; p = 0.02	r = 0.3; p = 0.004
HADS A	r = –0.06; p = 0.5	r = –0.1; p = 0.3	r = 0.05; p = 0.6
HADS D	r = –0.08; p = 0.4	r = 0.03; p = 0.7	r = 0.04; p = 0.7
SRT correct	r = 0.06; p = 0.5	r = –0.008; p = 0.9	r = –0.02; p = 0.8
SRT reaction time	r = –0.3; p = 0.008	r = –0.2; p = 0.07	r = –0.2; p = 0.05
VM1	r = 0.3; p = 0.007	r = 0.1; p = 0.2	r = 0.2; p = 0.05
VM2	r = 0.2; p = 0.02	r = 0.1; p = 0.2	r = 0.2; p = 0.06
VM3	r = 0.3; p = 0.002	r = 0.2; p = 0.1	r = 0.2; p = 0.02
VM4	r = 0.2; p = 0.02	r = 0.08; p = 0.4	r = 0.1; p = 0.1
VM5	r = 0.2; p = 0.03	r = 0.08; p = 0.4	r = 0.1; p = 0.2
VMDT	r = 0.3; p = 0.003	r = 0.2; p = 0.06	r = 0.2; p = 0.01
GnG reaction time	r = –0.3; p = 0.02	r = -0.2; p = 0.02	r = –0.2; p = 0.02
GnG correct Go	r = 0.2; p = 0.1	r = 0.1; p = 0.2	r = 0.1; p = 0.3
GNG incorrect NoGo	r = –0.2; p = 0.02	r = -0.2; p = 0.1	r = –0.1; p = 0.3

6MWT — six minutes walking test; AF — atrial fibrillation; BMI — body mass index; CKD-EPI — Chronic Kidney Disease Epidemiology Collaboration method; Cockcroft-Gault BSA — Cockroft–Gold method adjusted by body surface area; DM — diabetes mellitus; ECHO — echocardiography; GnG — GoNoGo test – incorrect Go answers, incorrect NoGo answers, correct Go answers, reaction time; HA — arterial hypertension; HADS A/D — Hospital Anxiety and Depression Scale: Anxiety/Depression; IHD — ischemic heart disease; IVSd — interventricular septal diastolic diameter; LA — left atrium; LVDd — left ventricular diastolic diameter; LVEF — left ventricular ejection fraction; LVPWd — left ventricular posterior wall diameter; MDRD4 — Modification of Diet in Renal Disease 4-variable version; NT-proBNP — N-terminal pro B-type natriuretic peptide; NYHA — the New York Heart Association; SRT — simple reaction test; VM 1–5 — verbal memory: trials 1, 2, 3, 4, 5; VMDT — verbal memory delayed test

observed that CrClCG-BSA covers the widest spectrum of results among the three methods tested (Tab. 1). These differences were attributable in part to age and body mass index (BMI) [9,16].

An interesting observation in the present analyses was that irrespective of which formula was applied (CG-BSA, MDR4, or CKD-EPI), patients with worse glomerular filtration results were hospitalized longer and had higher NT-pro BNP serum levels. This supports the hypothesis that glomerular filtration assessments are useful in terms of determining poor clinical status, as suggested by previous authors [10].

A significant correlation was also found between renal function parameters and the results of the 6MWT. For all three formulas, the lower the eGFR, the shorter the distance walked by the patient during the 6-minute-test period. Kitamura et al. [23] also reported an association between the daily level of motor activity and kidney function. As in the study by Zamora et al. [9], no significant association was found in the present cohort between renal function and echocardiographic parameters, irrespective of the used formula.

Value of three formulas in assessing glomerular filtration in terms of neuropsychological status

Research has shown that deterioration of kidney function is an independent risk factor for cognitive impairment [24, 25]. Although the present analyses also generated support for a correlation between decreased glomerular filtration and impaired cognitive function, strong, statistically significant associations were only found for CG-BSA. Associations with CKD-EPI were less pronounced (Tab. 3).

In the present analyses of cognitive function, the strongest correlations with reduced CG-BSA were

Table 4. Neuropsychological test results and 6MWT score in subgroups with GFR below and above 45 mL/min according to CG BSA

	CGBSA eGFR > 45 mL/min n = 65	**CGBSA eGFR < 45 mL/min n = 36**	**P-value**
Age [years]	70.0 (64.0–79.0)	78.5 (76.0–84.0)	0.14
6 MWT [m]	209.0 (155.0–300.0)	183.0 (125.0–225.0)	0.042
HADS A, n	6.0 (4.0–8.0)	6.5 (5.0–8.0)	0.42
HADS D, n	5.0 (3.0–8.0)	6.0 (3.0–8.0)	0.55
SRT correct, n	25.0 (25.0–25.0)	25.0 (25.0–25.0)	0.79
SRT reaction time [ms]	402.7 (278.5–654.9)	480.1 (368.2–822.3)	0.08
VM1, n	4.0 (3.0–5.0)	3.0 (2.0–4.0)	0.026
VM2, n	5.0 (4.0–7.0)	5.0 (3.0–6.0)	0.039
VM3, n	6.0 (5.0–7.0)	6.0 (4.0–6.0)	0.041
VM4, n	7.0 (5.0–8.0)	6.0 (5.0–7.0)	0.09
VM5, n	7.0 (5.0–8.0)	6.0 (5.0–7.0)	0.12
VMDT, n	5.0 (3.0–6.0)	4.0 (3.0–5.0)	0.047
GnG reaction time [ms]	387.3 (338.0–454.5)	409.5 (370.2–529.9)	0.23
GnG correct Go, n	72.0 (67.0–74.0)	71.5 (65.0–74.0)	0.43
GNG incorrect NoGo, n	6.0 (3.0–8.0)	7.0 (4.0–11.0)	0.13

6MWT — six minutes walking test; CKD-EPI — Chronic Kidney Disease Epidemiology Collaboration method; Cockcroft-Gault BSA — Cockroft–Gold method adjusted by body surface area; GnG — GoNoGo test – incorrect Go answers, incorrect NoGo answers, correct Go answers, reaction time; HADS A/D — Hospital Anxiety and Depression Scale: Anxiety/Depression; MDRD4 — Modification of Diet in Renal Disease 4-variable version; SRT — simple reaction test; VM 1–5 — verbal memory: trials 1, 2, 3, 4, 5; VMDT — verbal memory delayed test

found for reaction time and short-term and delayed verbal memory. These findings are consistent with those in the previous research. Silverwood et al. [26] applied similar neuropsychological tests and reported significant associations between renal function, reaction time, and verbal memory in patients with renal disease. Previous authors also described significant associations between the decreased excretory function of the kidneys and impairments in executive function, orientation, attention, and psychomotor speed [27]. However, severe chronic kidney disease is associated with global cognitive deficits [27].

The present analyses, like other research [27], found no correlation between deterioration in renal function and the severity of depressive and anxiety symptoms for any of the three assessing glomerular filtration formulas.

To our knowledge, no previous study has investigated the relationship between renal function, as measured using a spectrum of formulas, and cognitive function in geriatric patients with CHF. However, several reports have assessed the relationship between estimated renal function, as measured using a variety of methods, and mortality, as well as the predictive value of these methods, in patients with various states of disease [9, 11, 28–30]. Notably, many researchers have emphasized that the Cockcroft-Gault test has the highest prognostic value [9, 11, 16, 28, 31]. However, other tests have also been advocated [29]. In independent studies of correlations between renal function parameters and mortality in large heart failure (HF) cohorts, Szummer et al. [11], Zamora et al. [9], and Weidmann [31] demonstrated a predictive advantage for the Cockcroft-Gault formula. However, Weidmann's study investigated patients with acute HF [31]. A possible explanation for the predictive superiority of the CG-BSA formula over MDRD4 and CKD-EPI in patients with HF is the inclusion in the formula of the patient's weight [9] because CG-BSA shows the strongest association with BMI. This may be crucial because, as noted by previous authors, BMI correlates with mortality in the HF population [9, 32]. Excessive body weight is also an independent risk factor for cognitive decline [33]. Further studies in larger CHF cohorts are warranted to explain the present associations.

Conclusions

In conclusion, in our everyday clinical practice, we are using more and more sophisticated methods of assessing kidney function. In the context of cognitive functioning in the presented study, it was the Cockcroft-Gault formula that showed the strongest correlations of worse glomerular filtration with worse cognitive test results.

Limitations

There may be some possible limitations in this study. The sample size is quite small, therefore, further studies on a larger group of patients with diagnosed CHF could generate more accurate results. Another limitation of the study is related to the occurrence of comorbidities (e.g. Diabetes, arterial hypertension, arrhythmias) and other factors (such as age, body weight) in the examined patients, which may potentially affect both cognitive and renal functions.

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