

Comparison Of GFR Determined By Using Serum Cystatin C And Serum Creatinine Concentration Alone And In Combination For Diagnosis Of Hepatorenal Syndrome

Asma Helen Khan¹, Nooruddin Ahmad², Mamun Al Mahtab³ and Shahinul Alam⁴

¹Medical Officer, Department of Hepatology, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh

²Department of Hepatology, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh

³Head & Interventional Hepatology Division, Department of Hepatology, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh

⁴Department of Hepatology, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh

ABSTRACT

Introduction: Renal dysfunction is common in patients with liver cirrhosis, occurs about 19% of hospitalized patients with cirrhosis which have a huge impact on prognosis. Serum creatinine (Cr) is a widely used but less reliable marker to estimate glomerular filtration rate (GFR). Serum cystatin C (CysC) is a good endogenous marker to determine early renal impairment. Combined cystatin C and creatinine is an effective reflection of GFR. This study aimed to validate renal function by estimation of GFR using serum cystatin C and serum creatinine individually and combinedly. **Methods:** This was an observational cross sectional study, conducted in Department of Hepatology, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh. Thirty patients were cirrhosis with hepatorenal syndrome (HRS) and thirty were cirrhosis without HRS. **Result:** Mean value of serum creatinine, serum cystatin C, GFR by creatinine, GFR by cystatin C and GFR by (cre-cys) were statistically significant ($p < 0.05$) between two groups. All the study population were in Child Pugh B and C. Association of mean values of creatinine, cystatin C, GFR by creatinine, GFR by cystatin C and GFR by (cre-cys) with Child Pugh B and C were statistically significant in both groups. Based on ROC curves at cut-off value of 1.29 mg/ml cystatin C had sensitivity 96.7% and specificity 76.7% for detecting HRS. Coefficient of GFR by creatinine was -0.01 (CI -0.01 to 0.00) which was not statistically significant. Coefficient of GFR by cystatin C was -0.02 (CI -0.03 to 0.00) and GFR by (cre-cys) was 0.04 (CI 0.01 to 0.06) which were statistically significant for diagnosis of HRS. **Conclusion:** Com-

combined serum creatinine and cystatin C based GFR showed significant association to discriminate early renal impairment in patients with cirrhosis of liver.

Keywords: Serum Cystatin C, Serum Creatinine, hypovolaemia, pathophysiological

INTRODUCTION

Impairment of renal function in patients with liver cirrhosis is common; it has a huge impact on the patients' survival [1]. Moreover the severity of renal dysfunction usually progresses in parallel with advancement of the cirrhosis and portal hypertension. Therefore parameters of impaired renal function are valuable and close monitoring of renal function is of great clinical importance. Hepatorenal syndrome is a major complication of cirrhosis of liver with ascites. HRS is the most advanced stage of the various pathophysiological derangement that take place in cirrhosis [2]. Acute renal dysfunction occurs in 15-20% of hospitalized patient with cirrhosis. HRS is found in 10-13% of such patients and appears to be an extension of pathophysiology of prerenal azotaemia and therefore potentially reversible. Annual frequency of HRS in patient with cirrhosis 8% and some reports as high as 40% [3]. HRS is a functional renal failure caused by intrarenal vasoconstriction which occur in patient with end stage liver disease and circulatory dysfunction [4]. It is characterized by splanchnic vasodilatation with a relatively low cardiac output leading to effective hypovolaemia. GFR is universally considered as a measure of overall function of kidney. Serum creatinine is most widely used marker for noninvasive GFR estimation in

Correspondence to
Asma Helen Khan

clinical practice. However it is a poor guide to estimate GFR. Decrease hepatic production of creatinine, muscle atrophy, reduced protein intake especially in patient with liver cirrhosis account for an increased gap between serum creatinine level and actual renal function [5]. Cirrhotic patients often have normal creatinine level in presence of moderate or severe renal impairment. As a result it may overestimate GFR compared with actual renal dysfunction. So, its role is thus limited for the detection of mild or moderate renal injury in cirrhotic patient [6]. Serum cystatin C is a non-glycosylated low molecular weight protein, almost never influenced by external factors such as age, gender, muscle mass, inflammation. It has been proposed as a novel biomarker of the renal function [7]. It reflects GFR more accurately than serum creatinine. Cystatin C can help to detect early renal injury as it increases earlier than creatinine when GFR declines [8, 9]. In patients with cirrhosis of liver serum cystatin C may be more effective than serum creatinine in measurement of renal function [10]. So, cystatin C is considered as a good parameter to estimate GFR for detection of HRS development and to assess survival in these patients.

METHODOLOGY

This observational cross sectional study was conducted in the Department of Hepatology, Bangabandhu Sheikh Mujib Medical University (BSMMU) from July 2014 to June 2017. The diagnosis of cirrhosis was based on a combination of clinical, laboratory and ultrasonographic findings. Total 50 patients were enrolled in this study. Cirrhotic patient who met the criteria of hepatorenal syndrome [10] considered as case. Age & sex matched cirrhotic patient without HRS visited outpatient and admitted inpatient department as control. Patients aged 18-60 years were eligible for the study. Patients were excluded if they had intrinsic renal disease, cardiac failure, malignancy, thyroid disorder. Sample for serum creatinine and serum cystatin C were sent to Biochemistry and Microbiology department respectively. The local ethical committee approved the study. A written informed consent was obtained from all participating patients prior to include in the study. Serum creatinine was measured by kinetic jaffe's method on Automated Biochemical analyzer (Olympus AU 400). Serum cystatin C was measured by ELISA method using cystatin C kit on a CX7 analyzer. GFR was calculated using three estimating formula, modification of diet in renal disease (MDRD) by 4 variables, Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) using cystatin C alone (CKD-EPIcys) and both creatinine and cystatin C (CKD-EPIcre-cysC).

GFR was estimated by using formula:

A) Serum creatinine based GFR: MDRD

$$1.86 \text{ creatinine}^{-1.154} \times \text{age}^{-0.203} \times 0.742 \text{ (F) [11]}$$

B) Serum Cystatin C based GFR: CKD – EPI

$$127.7 \times \text{cystatin C}^{-1.17} \times \text{age}^{-0.13} \times 0.91 \text{ (F) [12]}$$

C) Serum creatinine – cystatin C based GFR: CKD – EPI

$$6 \times (s / \text{creatinine in mg/dl} - 0.65) \times (s / \text{cystatin C in mg/l} - 0.57) \times \text{age}^{-0.2} \times 0.82 \text{ (F) [13]}$$

Statistical analysis was carried out by using the Statistical Package for Social Sciences version 23.0 for Windows (SPSS Inc., Chicago, Illinois, USA). Student t-test was used to analyze the categorical variables, shown with cross tabulation. Receiver operating characteristic (ROC) curves was generated to determine the cut off value for the best sensitivity, specificity, negative and positive predictive values of Creatinine, Cystatin C, GFR by cystatin C, GFR by creatinine and GFR by cre-cys to diagnose HRS. P values <0.05 was considered as statistically significant.

RESULTS

Baseline characteristics data of the enrolled patients are presented in Table 1. The mean age was found 50.2 ± 10.3 years in case group and 43.9 ± 11.2 years in control group. Majority (96%) patients were male in case group and 80.0% in control group. Mean serum creatinine was found 2.97 ± 3.05 mg/dl in case group and 0.96 ± 0.25 mg/dl in control group, and mean serum cystatin C was found 2.4 ± 1.04 mg/L in case group and 1.08 ± 0.35 mg/L in control group. The mean GFR by creatinine was found 34.36 ± 10.43 ml/min in case group and 96.76 ± 34.78 ml/min in control group, mean GFR by cystatin C was 30.6 ± 10.71 ml/min in case group and 82.73 ± 28.49 ml/min in control group. The mean GFR by cre-cys was found 30.53 ± 9.4 ml/min in case group and 86.9 ± 27.46 ml/min in control group. The mean differences were statistically significant ($p < 0.05$) between two groups (Table 2). HBsAg was found in 60.0% cases and 86% controls. Anti HCV was found in 16% cases. In Child Pugh B (7-9 score), mean creatinine, cystatin C, GFR by creatinine, GFR by cystatin C and GFR by cre-cys were statistically significant ($p < 0.05$) between case and control groups. In Child Pugh C (10-13 score), mean creatinine, cystatin C, GFR by creatinine, GFR by cystatin C and GFR by cre-cys were also statistically significant ($p < 0.05$) between case and control groups (Table 3).

Based on ROC curves serum creatinine at cut off value of 1.38 mg/dl had sensitivity 100.0% and specificity 96.7% for diagnosis of HRS, Serum cystatin C at cut-off value of 1.29 mg/ml had sensitivity 96.7% and specificity 76.7% for HRS. At cut-off value of 32.5 ml/min of GFR by cystatin C had sensitivity 46.7% and specificity 3.3%, 42.5ml/min of

Table 1 Baseline characteristics of the study population.

Variable	Mean	±SD	Min	-max
Age (years)	47.1	±11.1	18.0	-60.0
BMI (kg/m ²)	23.4	±3.0	18.0	-35.4
SBP (mmHg)	98.2	±11.9	40.0	-120.0
DBP (mmHg)	67.6	±7.6	50.0	-80.0
Creatinine (mg/dl)	1.96	±2.37	0.52	-18.0
Cystatin C (mg/L)	1.74	±1.02	0.62	-6.90
GFR by creatinine (ml/min)	65.57	±40.47	9	-180
GFR by cystatin C (ml/min)	56.67	±33.86	5	-126
GFR by cre-cys (ml/min)	58.71	±34.95	7	-132
Child-Pugh score	10.3	±1.6	7.0	-13.0
Serum sodium (mmol/L)	129.3	±5.9	116.0	-146.0
Serum potassium (mmol/L)	4.1	±0.7	2.7	-6.0
Ascitic fluid	-	-	-	-
TC (cumm)	576.7	±1583.8	20.0	-9000.0
Neutrophil (%)	29.9	±25.0	4.0	-90.0
Lymphocyte (%)	70.1	±25.0	10.0	-96.0
Total protein (gm/dl)	1.1	±0.5	0.1	-2.6
SAAG (gm/dl)	1.8	±0.4	1.0	-3.0

Table 2 Mean creatinine, cystatin C, GFR by creatinine, GFR by cystatin C and GFR by (cre-cys) of the study population.

	Case (n=25)		Control (n=25)		P value
	Mean	±SD	Mean	±SD	
Creatinine (mg/dl)	2.97	±3.05	0.96	±0.25	0.013 ^s
Cystatin C (mg/L)	2.4	±1.04	1.08	±0.35	0.021 ^s
GFR by creatinine (ml/min)	34.36	±10.43	96.76	±34.78	0.001 ^s
GFR by cystatin C (ml/min)	30.6	±10.71	82.73	±28.49	0.001 ^s
GFR by cre-cys (ml/min)	30.53	±9.4	86.9	±27.46	0.001 ^s

s=significant

P value reached from unpaired t-test

Table 3 Association between creatinine, cystatin C, GFR by creatinine, GFR by cystatin C and GFR by (cre - cys) with Child Pugh.

Child Pugh	Case Mean±SD	Control Mean±SD	P value
B score (n=16)	(n =6)	(n =10)	
Creatinine (mg/dl)	2.29±0.76	0.95±0.23	0.001 ^s
Cystatin C (mg/L)	2.41±0.94	1.07±0.35	0.001 ^s
GFR by creatinine (ml/min)	34.57±10.1	95.08±35.75	0.001 ^s
GFR by cystatin C (ml/min)	28.57±9.74	82.17±30.27	0.001 ^s
GFR by cre-cys (ml/min)	30.0±9.38	87.0±28.15	0.001 ^s
C score (n=34)	(n =20)	(n =14)	
Creatinine (mg/dl)	3.18±3.45	0.98±0.28	0.011 ^s
Cystatin C (mg/L)	2.41±1.09	1.1±0.37	0.001 ^s
GFR by creatinine (ml/min)	34.3±10.76	97.89±35.12	0.001 ^s
GFR by cystatin C (ml/min)	31.22±11.12	83.11±28.14	0.001 ^s
GFR by cre-cys (ml/min)	30.7±9.61	86.83±27.82	0.001 ^s

s= significant

P value reached from unpaired t-test

Table 4 Receiver-operator characteristic curves of creatinine, cystatin C, GFR by cystatin C, GFR by creatinine and GFR by (cre - cys) for prediction of HRS.

	Cut of value	Sensitivity	Specificity	Area under the ROC curve	95% CI Lower bound	Upper bound
Creatinine	1.38	100.0	96.7	1.000	1.000	1.000
Cystatin C	1.29	96.7	76.7	0.974	0.943	1.000
GFR by cystatin C	32.5	46.7	3.3	0.026	0.000	0.063
GFR by creatinine	42.5	26.7	3.3	0.013	0.000	0.034
GFR by cre-cys	38.5	10.0	0.0	0.004	0.000	0.013

GFR by creatinine had sensitivity 26.7% and specificity 3.3% and 38.5ml/min of GFR by cre-cys had sensitivity 10.0% and specificity 0.0% for HRS (Table 4).

Coefficient of GFR by creatinine was -0.01 (CI -0.01 to 0.00) which was not statistically significant. Coefficient of GFR by cystatin C was -0.02 (CI -0.03 to 0.00) and GFR by (cre - cys) was 0.04 (CI 0.01 to 0.06) which were statistically significant (Table 5).

DISCUSSION

This observational cross sectional study was conducted in the Department of Hepatology, BSMMU. During the study period from July 2014 to June 2017, total 50 patients were admitted at inpatient and visited outpatient department were enrolled. Thirty patients were cirrhosis with HRS considered as cases and 30 patients were cirrhosis without HRS as control. In this present study showed in case group 52% patients were belonged to age 51-60 years and in control group 46% were in 41-50 years. The mean age difference was statistically significant ($p < 0.05$) between two groups. Murty et al. [14] found similar relationship. In our study majority patients were male, 96.7% in case group and 80.0% in control group. The median serum creatinine level was significantly lower in women than men (0.7 vs. 0.9 mg/dl, $P = 0.015$), but there was no significant difference in median cystatin C levels (1.0 vs. 1.1 mg/L, $P = 0.545$) and mGFR (74.5 vs. 77.9 ml/min/1.73 m², $P = 0.973$) between women and men. Age, female sex were an independent predictor of serum creatinine level ($\beta = -0.205$, $P = 0.007$), but not of serum cystatin C level ($\beta = -0.055$, $P = 0.526$). In this study the mean creatinine, cystatin C, GFR by creatinine, GFR by cystatin C and GFR by cre-cys were statistically significant ($p < 0.05$) between case and control groups. Murty et al. observed [14] the mean serum creatinine was high in AKI group

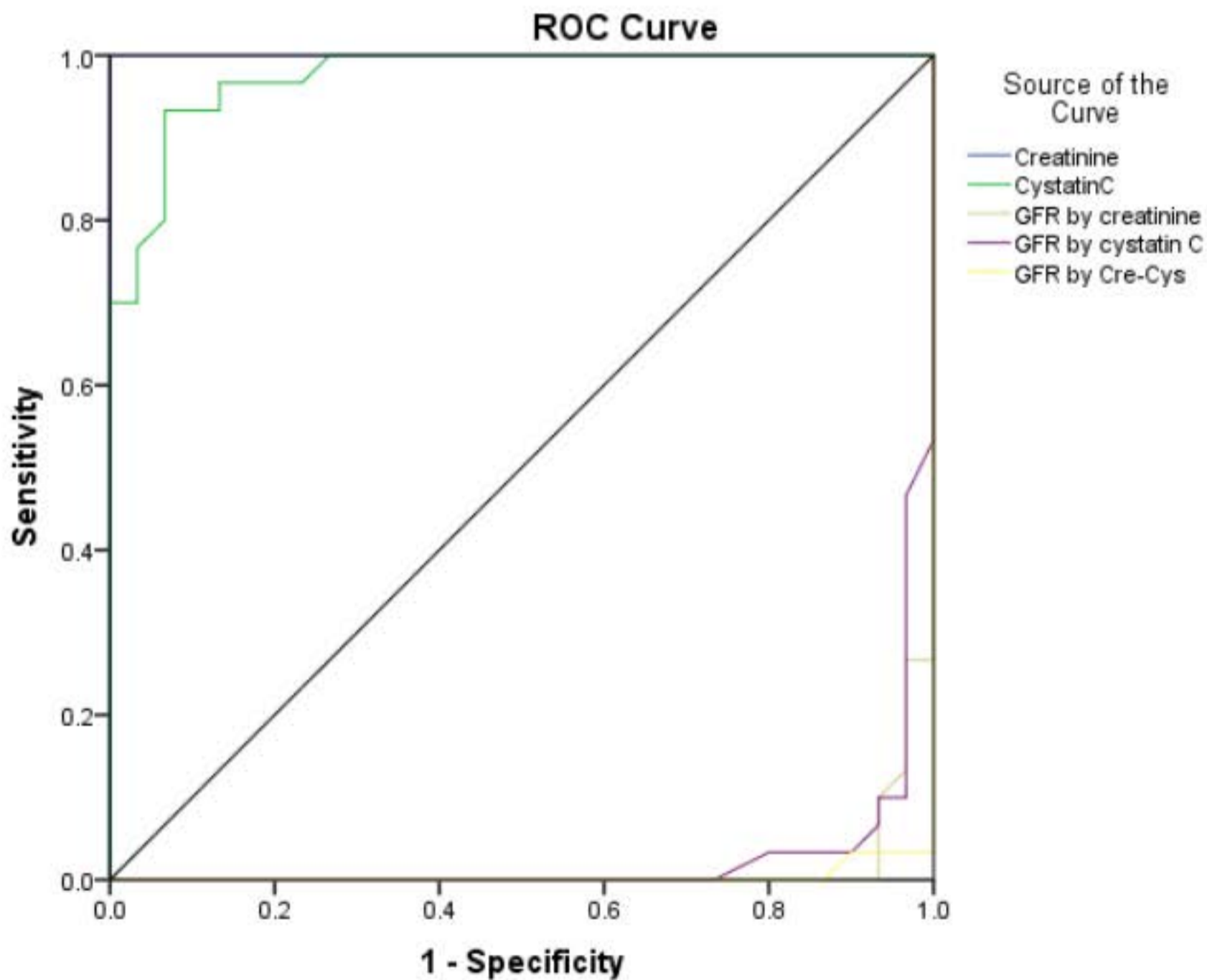
than healthy group. Culafic et al. [15] measured cystatin C in patients with liver cirrhosis and they have confirmed significantly higher cystatin C in patients with cirrhosis ($p = 0.036$). El-Agroudy et al. [16] also showed mean differences of creatinine, cystatin C, GFR which were statistically significant ($p < 0.05$) between case and control groups. Regarding etiology HBsAg, anti HCV and non viral causes were detected. In cases group, 60.0% were HBsAg positive, 16.7% were anti HCV positive and 23.3% were non viral. In control group, 86.7% patients were HBsAg positive, 13.3% were non viral and no anti HCV was detected. All enrolled patients were in Child Pugh B and C class. We showed that 76.7% cases and 60.0% controls were in CP-C, where as 23.3% cases and 40.0% controls were in CP-B. In the study of Omar et al. [17] most patients were Child-Pugh class C (74.3%) and Child-Pugh class B (25.7%). Both in Child Pugh B and C, mean creatinine, cystatin C, GFR by creatinine, GFR by cystatin C and GFR by cre-cys were statistically significant ($p < 0.05$) between case and control groups. In Culafic et al. [15] study post-hoc comparisons showed statistically significant differences in values of cystatin C between Child-Pugh A and B ($P = 0.014$). Woitas et al. [18] in their study found that cystatin C was significantly higher in Child-Pugh B and C patients when compared to Child-Pugh A patients. Another study of El-Agroudy et al also showed mean creatinine 0.88±0.31 mg/dl in Child Pugh B group and mean serum cystatin C 2.7±0.67 mg/l in Child Pugh C group. In the study of Gerbes et al. [19] the sensitivity of cystatin C (86.7%) tended to be higher than that of creatinine (60.0%; NS) and urea (53.3%; NS) at equal specificity of 60%. The area under the receiver-operator characteristic (ROC) curves for the HRS predictors is depicted in Figure 1. Receiver-operator characteristic (ROC) were constructed using creatinine, cystatin C, GFR by cystatin C, GFR by creatinine and GFR by cre-cys of the patients with HRS,

Table 5 Multivariable regression analysis for association between GFR by creatinine, GFR by cystatin C and GFR by (cre-cys)

	Coefficients	P value	95% CI	
			Lower	Upper
GFR by creatinine	-0.01	0.13 ^{ns}	-0.01	0.00
GFR by cystatin C	-0.02	0.02 ^s	-0.03	0.00
GFR by cre-cys	0.04	0.001 ^s	0.01	0.06

s=significant, ns= not significant

Multivariable logistic regression analysis was performed



Diagonal segments are produced by ties.

Figure 1 1 : Receiver-operator characteristic curves of creatinine, cystatin C, GFR by cystatin C, GFR by creatinine and GFR by cre-cys.

which gave a creatinine cut off value of 1.38 mg/dl with a best combination of sensitivity 100.0% and specificity 96.7% for diagnosis of HRS. At cut-off value of 1.29 mg/l the sensitivity and specificity of cystatin C in diagnosing HRS were found to be 96.7% and 76.7%, respectively. At cut off value of 32.5 ml/min the sensitivity and specificity of GFR by cystatin C were found to be 46.7% and 3.3%, respectively. At this cut-off value of 42.5 ml/min the sensitivity and specificity of GFR by creatinine were found to be 26.7% and 3.3%, respectively. At cut-off value 38.5 ml/min the sensitivity and specificity of GFR by cre-cys were 10.0% without specificity. Omar et al. [17] showed ROC curves which were coordinated to define cutoff values with acceptable sensitivity and specificity for the studied tests and formulae. One strong limitation of serum creatinine and creatinine based equations was that serum creatinine lags behind a decreasing GFR [20]. So they are not accurately reflecting the present status of the renal function of the patient, a limitation that has been overcome by serum cystatin C that proved to accurately reflect the early stages of renal impairment according to the results of this study. Another study by El-Agroudy et al. [16] revealed serum cystatin C had higher sensitivity and specificity than serum creatinine in the studied subjects. At cut off value of 1.2 mg/l cystatin C had the highest sensitivity for patients group while in control group creatinine had highest sensitivity at cut off value 0.8 mg/dl. Wang D et al showed serum cystatinC and eGFR cys are superior to serum creatinine and eGFR cre in diagnosis of secondary renal impairment of hepatic cirrhosis where cystatinC at cut off value 1.24 showed sensitivity 87.6% and specificity 93.1%. At cut off value of 63.4 ml/min eGFRcys showed sensitivity 87% and specificity 94.4%. [21] Correlation coefficient of GFR by creatinine was -0.01 (CI -0.01 to 0.00) which was not statistically significant. Correlation coefficient of GFR by cystatin C was -0.02 (CI -0.03 to 0.00) and GFR by (cre - cys) was 0.04 (CI 0.01 to 0.06) which were statistically significant. Omar et al. [17] showed different measures and estimated the renal functions which were correlated with the isotopic GFR using Pearson's correlation. CKD-EPI (cr-cys) had the highest R² among all other measures. Murty et al. [14] showed multiple logistic regression applied to GFR calculated serum creatinine and serum cystatin C in AKI group. Cystatin C based GFR resulted in more negative correlation compared to creatinine based GFR in the AKI group. The p value was significant (p< 0.01) for GFR (cysC-cre).

CONCLUSION

For proper detection and treatment of any progressive disease a highly sensitive test is required. Renal impairment usually

have a huge impact on the prognosis of liver cirrhosis. So, establishment of a good marker for renal function is of utmost important. Our study found that estimated GFR by using combined serum creatinine and serum cystatin C was the best measure that reflect actual renal performance to detect early stages of renal impairment in patients with cirrhosis of liver.

REFERENCES

- 1 A Slack, A Yeoman, and J Wendon. Renal dysfunction in chronic liver disease. *Critical Care*, 14(2):214–214, 2010.
- 2 K Moore, J Wendon, M Frazer, J Karani, R Williams, and K Badr. Plasma endothelin immunoreactivity in liver disease and the hepatorenal syndrome. *N Engl J Med*, 327:1774–1778, 1992.
- 3 V Arroyo, J Fernandez, and P Gines. Pathogenesis and treatment of hepatorenal syndrome. *Seminars in Liver Disease*, 28(1):81–95, 2008.
- 4 K Lenz. HRS: is it normal hypovolemia, a cardiac disease of part Gradually Developing multiorgan dysfunction. *Hepatology*, pages 263–264, 2005.
- 5 Y S H S Ahn, S G Kim, and Kim. CystatinC is a good predictor of hepatorenal syndro and survival in patients with cirrhosis who have normal serum creatinine level. *Hepato Gastroenterology*, 59:1168–117, 2012.
- 6 J Macaulay, B Thompson, D C Kiberd, K M Barnes, and Peltekian. Serum creatinine in patients with advanced liver disease is of limited value for identification of moderate renal dysfunction:are the equations for estimating renal function better? *Canadian Journal of Gastroenterology*, 20(8):521–526, 2006.
- 7 E Randers and E J Erlandsen. Serum cystatin C as an endogenous marker of the renal function-a review. *Clin Chem. Lab Med*, 37:389–395, 1999.
- 8 P Sjostrom, M Tidman, and I Jones. Determination of the production rate and non-renal clearance of cystatin C and estimation of glomerular filtration rate from the serum concentration of cystatinC in human. *J Clin Lab Invest*, 65:111–124, 2005.
- 9 S Demirtas, A Barbas, A Akbay, Y Yavuz, and L Karaca. Diagnostic value of serum cystatin C for evaluation of hepatorenal syndrome. *Clin Chem Acta*, 311:81–89, 2001.
- 10 F Salerno, A Gerbes, P Gines, F Wong, and V Arroyo. Diagnosis, prevention and treatment of hepatorenal syndrome in cirrhosis. *Gut*, 56:1310–1318, 2007.

- 11 A S Levey, J P Bosch, J B Lewis, T Greene, N Rogers, and D Roth. A more accurate method to estimate glomerular filtration. *Ann Intern Med*, 130(6):461–70, 1999.
- 12 L A Stevens, J Coresh, C H Schmid, H I Feldman, M Froissart, and J Kusek. Estimating GFR using serum cystatin C alone and in combination with serum creatinine: a pooled analysis of 3,418 individuals with CKD. *Am J Kidney Dis*, 51(3):395–406, 2008.
- 13 A L Mindikoglu, T C Dowling, M R Weir, S L Seliger, R H Christenson, and L S Magder. Performance of Chronic Kidney Disease Epidemiology Collaboration Creatinine-CystatinC Equation for Estimating Kidney Function in Cirrhosis. *Hepatology*, 59(4):1532–1542, 2014.
- 14 Msn Murty, U K Sharma, U B Pandey, and S B Kankare. Serum cystatinC as a marker of renal function in detection of early acute kidney injury. *Indian J Nephrol*, 23(3):180–183, 2013.
- 15 D Culafic, M Stulic, R Obrenovic, D Miletic, D Mijac, and M Stojkovic. Role of cystatin C and renal resistive index in assessment of renal function in patients with liver cirrhosis. *World Gastroenterol*, 20(21):6573–6579, 2014.
- 16 A El-Agroudy, A A Sabry, H A Ghanem, A El-Baz, A Fakhry, and H M Gad. Serum cystatin C: a good marker for evaluation of glomerular filtration rate in hepatorenal syndrome. *Eur J Gen Med*, 1(4):29–35, 2004.
- 17 M Omar, W Abdel-Razek, G Aba-Raia, M Assem, and G El-Azab. Evaluation of serum cystatin C as a marker of early renal impairment in patient with liver cirrhosis. *International Journal of Hepatology*, 2015:1–8.
- 18 R P Woitas, B Stoffel-Wagner, S Flommersfeld, U Poege, P Schiedermaier, and H U Klehr. Correlation of serum concentrations of cystatin C and creatinine to inulin clearance in liver cirrhosis. *Clin Chem*, 46:712–715, 2000.
- 19 A L Gerbes, V Gulberg, M Bilzer, and M Vogeser. Evaluation of serum cystatin C concentration as a marker of renal function in patients with cirrhosis of liver. *Gut*, 50(1):106–110, 2002.
- 20 S Herget-Rosenthal, J Metzger, A Albalat, V Bitsika, and H Mischak. Proteomic biomarkers for the early detection of acute kidney injury. *Prilozi*, 33(1):27–48, 2012.
- 21 D Wang, J F Feng, A Q Wang, Y W Yang, and Y Liu. Role of cystatin C and glomerular filtration rate in diagnosis of kidney impairment in hepatic cirrhosis patients. *Medicine*, 96(e6949), 2017.