# Early echocardiographic signs of diastolic dysfunction predict acute kidney injury in cirrhotic patients

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## Abstract

**Background:** Cardiovascular dysfunction in cirrhotic patients affects survival and the development of cirrhotic complications. We aimed to evaluate potential echocardiographic parameters to predict mortality and acute kidney injury (AKI) in cirrhotic patients.

**Methods:** A total of 103 cirrhotic patients who underwent echocardiography between February 2009 and August 2016 in Taipei Veterans General Hospital were retrospectively enrolled. Cardiac function was evaluated using transthoracic two-dimensional echocardiography with tissue Doppler imaging. Cox hazard regression analysis was used for assessing predictors for 1-year mortality and AKI within 1 year.

**Results:** Baseline echocardiographic parameters were similar between survivors (n = 92) and nonsurvivors (n = 11). Lower serum levels of albumin, as well as higher albumin-bilirubin (ALBI) scores, Child-Pugh scores, and model for end-stage liver disease scores were observed in nonsurvivors. Cox proportional hazard regression analysis revealed Child-Pugh score as the only predictor of 1-year mortality. Baseline serum creatinine (Cr) > 1.5 mg/dL, total bilirubin > 2 mg/dL, and a higher E/e′ ratio predict occurrence of AKI within 1 year. Among patients with serum Cr < 1.5 mg/dL, an increased atrial filling velocity and higher ALBI scores predict AKI occurrence within 1 year.

**Conclusion:** Severity of underlying liver disease but not echocardiographic parameters predicts 1-year mortality in cirrhosis. Early echocardiographic signs of diastolic dysfunction and higher ALBI scores may predict development of AKI in cirrhotic patients with serum Cr < 1.5 mg/dL.

**Keywords:** Acute kidney injury; Cardiomyopathies; Echocardiography; Liver cirrhosis

## 1. INTRODUCTION

Cirrhotic cardiomyopathy plays an important role in the development of several complications of liver cirrhosis, such as ascites, spontaneous bacterial peritonitis (SBP), hepatorenal syndrome (HRS),[1–4] and is associated with poor prognosis.[1–3,5,6] Some studies have demonstrated that diastolic dysfunction is related to adverse outcomes following transjugular intrahepatic portosystemic shunts insertion[7] and is a leading cause of mortality after liver transplantation.[8,9]

Diagnostic and supportive criteria for cirrhotic cardiomyopathy were proposed by the 2005 World Congress of Gastroenterology,[10] which was mainly based on the echocardiographic finding of systolic and/or diastolic dysfunction and electrocardiographic changes. In fact, cirrhotic cardiomyopathy remains occult with nearly normal cardiac function in most patients during the clinical course of liver cirrhosis and is only unmasked upon exercise or stress, which increases the difficulty in the early detection of cirrhotic cardiomyopathy.

Currently, researches have used echocardiographic parameters to investigate the association between cardiovascular alteration and outcomes in cirrhosis.[1–3,5,6,11] Acute kidney injury (AKI), including HRS, is one of the most severe complications of cirrhosis and is associated with higher mortality among cirrhotic patients. [12–16] Early identification of patients at high risk of developing AKI may help to improve their outcomes. Several biomarkers, such as urine neutrophil gelatinase-associated lipocalin and serum cystatin C, have been proposed as potential early predictors of AKI in cirrhotic patients.[17–19] Nevertheless, these biomarkers are not yet widely available in clinical practice and there are still patients who are at high risk for AKI that may not be detected. Echocardiography is a simple and noninvasive clinical tool with the potential to identify patients who are at high risk for AKI. Cardiac index and E/e′ ratio, an important

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echocardiographic parameter for left ventricular (LV) diastolic dysfunction, have been reported as independent prognostic factors for development of HRS.[1,3,5] However, no studies have investigated the predictive value of echocardiographic parameters in AKI. In this study, we aimed to evaluate the predictive value of echocardiographic parameters for survival and development of AKI among cirrhotic patients.

## 2. METHODS

### 2.1. Study design and patient selection

A total of 103 consecutive cirrhotic patients who received echocardiography due to clinical suspicion of cirrhotic cardiomyopathy between February 2009 and August 2016 in Taipei Veterans General Hospital were enrolled retrospectively. Liver cirrhosis was diagnosed based on clinical findings, laboratory data, imaging studies, and endoscopic findings for all patients. The presence of ascites was detected by abdominal ultrasound. Patients were excluded if they were <18 years old, loss to follow up during the study period, and had congenital heart disease or ever received cardiac surgery. The diagnosis of cirrhotic cardiomyopathy was based on the criteria proposed by 2005 World Congress of Gastroenterology.[10] This study was approved by the Institutional Review Board of Taipei Veterans General Hospital.

### 2.2. Data collection

Demographic characteristics, laboratory data, and underlying comorbidity were collected retrospectively by reviewing patients' medical records. The laboratory parameters were recorded within 2 weeks following echocardiography as baseline liver, renal, and coagulation function. The presence of ascites was recorded from abdominal sonography performed within 3 months prior enrollment. Severity of underlying liver disease was measured using the Child-Pugh score and model for end-stage liver disease (MELD) score. Albumin-bilirubin (ALBI) score was also calculated at enrollment. During the 1-year follow-up period, newly developed complications of liver cirrhosis, including SBP, hepatic encephalopathy, and variceal bleeding, were recorded. The definition of AKI was based on criteria of International Club of Ascites.[20]

### 2.3. Electrocardiographic and echocardiographic examinations

On electrocardiographic examinations, the corrected QT interval (QTc) was calculated using Bazett's formula. On echocardiographic examinations, two-dimensional and Doppler transthoracic echocardiography was performed, and the initial echocardiographic parameters were used for this analysis. All measurements were made according to the recommendations of the American Society of Echocardiography.[21] LV dimensions and ejection fraction were measured by modified biplane Simpson's method.[21] The mitral inflow velocities were assessed by pulsed-wave Doppler at the tips of the mitral valve from apical four-chamber scans. The following echocardiographic parameters were evaluated: peak early filling velocity (E), atrial (late) diastolic filling velocity (A), calculated E/A ratio (E/A), early wave deceleration time (DT), early diastolic mitral annular velocity of the septal sites (e′), calculated E/e′ ratio (E/e′), and right ventricular systolic pressure (RVSP).

### 2.4. Statistical analysis

Data were expressed as mean ± standard deviation or as counts, as appropriate. The $\chi^2$ or Fisher's exact test was used to analyze categorical variables. The Mann-Whitney *U* test was applied for assessing continuous variables. The Cox proportional-hazards model was used to identify factors associated with an increased risk of death and AKI in 1 year. The results of the Cox regression analysis were reported as *p* value, hazard ratio (HR), and 95% confidence interval (CI). All statistical analyses were performed using IBM SPSS Statistics for Windows, version 24.0 (IBM Corp., Armonk, NY, USA).

## 3. RESULTS

### 3.1. Characteristics of cirrhotic patients

Clinical, demographic, biochemical, and echocardiographic data are summarized in Table 1. Patients were predominantly male (72.8%) with a median age of 68.5 years. Most patients were Child-Pugh class B (61.2%) and postviral cirrhosis (68.9%) was the major cause of liver cirrhosis. There were no significant differences between survivors and nonsurvivors in terms of age, sex, mean arterial pressure, underlying comorbidities, or use of certain cardiovascular medications, including angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, nonselective β blockers, and statins. However, lower serum levels of albumin (2.95 ± 0.48 mg/dL vs 3.38 ± 0.60 mg/dL, $p = 0.031$) and higher ALBI scores (–1.65 ± 0.41 vs –2.11 ± 0.57), Child-Pugh scores (8.18 ± 1.66 vs 6.13 ± 1.29, $p < 0.001$), and MELD scores (17.9 ± 7.75 vs 13.2 ± 5.95, $p = 0.025$) were observed in nonsurvivors than in survivors. Baseline echocardiographic parameters did not differ between groups. Notably, increased QTc interval, septal E/e′ ratio and RVSP were found in both groups of cirrhotic patients. In addition, baseline echocardiographic parameters did not differ between patient with and without nonselective beta-adrenergic blocker use. A high proportion of presence of ascites was found among nonsurvivors (54.5% vs 17.4 %, $p = 0.004$). Rate of newly developed complications of cirrhosis was similar between the two groups. AKI was the most commonly observed complication (37.6%) of cirrhosis after excluding cases who underwent hemodialysis or peritoneal dialysis. No patients in this study died before AKI onset. Mortality rate of these cirrhotic patients was 10.7% at 1-year follow-up.

### 3.2. Clinical outcomes at 1-year follow-up

Overall survival at 1 month, 3 month, 6 month, and 1 year was 97.1%, 95.1%, 94.1%, and 89.3%, respectively. Multivariate Cox regression analysis (Table 2) using parameters associated with 1-year mortality is shown in Table 1. The only significant predictor for 1-year mortality in cirrhotic patients was the Child-Pugh score (HR = 1.99, 95% CI = 1.04-3.80, $p = 0.037$).

Thirty-five patients developed AKI within 1 year of follow-up. The cumulative incidence rates of AKI-free survival at 1 month, 3 month, 6 month, and 1 year were 88.6%, 75.8%, 69.9%, and 58.1%, respectively. Table 3 shows the demographic, biochemical, and echocardiographic features between those who did not develop AKI (n = 58) and those who developed AKI (n = 35) after excluding 10 patients with end-stage renal disease undergoing regular hemodialysis or peritoneal dialysis. In the group without AKI events, five patients had chronic kidney disease (CKD), of which 2 patients were diagnosed with CKD stage IIIA and 3 patients with CKD stage V. In the group with AKI events, 10 patients had CKD, of which 2 patients were diagnosed with CKD stage IIIA, 3 patients with CKD stage IIIB, 2 patients with CKD stage IV, and 3 patients with CKD stage V. Patients who developed AKI had higher levels of baseline serum creatinine, total bilirubin (TB), and higher MELD scores. Interestingly, increased atrial filling velocity, lower E/A ratio, septal e′, and higher E/e′ ratio were also observed among patients with AKI in 1 year. In a multivariate Cox hazard regression analysis excluding MELD score (Table 4; model 1), the significant predictors were serum creatinine (Cr) > 1.5 mg/dL, TB > 2 mg/dL, and septal E/e′. When MELD score was included (Table 4; model 2),

**Table 1**

**Comparison of demographic, echocardiographic characteristics and complications of cirrhosis between survivors and nonsurvivors at 1 year of follow-up**

| Variables | Survivor (n = 92) | Nonsurvivor (n = 11) | *p* |
|---|---|---|---|
| Age, y | 67.86 ± 15.57 | 74.00 ± 11.23 | 0.217 |
| Male | 66 (71.7) | 9 (81.8) | 0.478 |
| Cause of cirrhosis (%) | | | |
| Viral | 63 (68.5) | 8 (72.9) | 1.000 |
| Alcohol | 8 (8.7) | 2 (18.2) | 0.315 |
| Other | 21 (22.8) | 1 (9.1) | 0.293 |
| Mean arterial pressure, mmHg | 89.34 ± 14.08 | 89.00 ± 10.21 | 0.953 |
| Laboratory | | | |
| Platelet, 1000/μL | 134.13 ± 103.56 | 141.84 ± 48.79 | 0.525 |
| Sodium, mEq/L | 135.45 ± 0.73 | 137.45 ± 5.94 | 0.855 |
| Cr, mg/dL | 1.56 ± 1.30 | 2.03 ± 1.32 | 0.297 |
| TB, mg/dL | 1.34 ± 2.80 | 4.28 ± 6.34 | 0.062 |
| Albumin, g/dL | 3.38 ± 0.60 | 2.95 ± 0.48 | 0.031 |
| INR | 1.15 ± 0.23 | 1.11 ± 0.43 | 0.608 |
| Comorbidity | | | |
| Diabetes | 33 (35.9) | 6 (54.5) | 0.227 |
| Pulmonary | 15 (16.3) | 1 (9.1) | 0.532 |
| Hypertension | 64 (69.6) | 7 (63.6) | 0.688 |
| Congestive heart failure | 11 (12.0) | 2 (18.2) | 0.557 |
| Coronary artery disease | 24 (26.1) | 3 (27.3) | 0.933 |
| Renal | 22 (23.9) | 2 (18.2) | 0.671 |
| Neurologic | 7 (7.6) | 2 (18.2) | 0.241 |
| Malignancy | 31 (33.7) | 7 (63.6) | 0.094 |
| Cirrhotic cardiomyopathy | 60 (65.2) | 7 (63.6) | 0.917 |
| Presence of ascites | 16 (17.4) | 6 (54.5) | 0.004 |
| ALBI score | -2.11 ± 0.57 | -1.65 ± 0.41 | 0.016 |
| Child-Pugh score | 6.13 ± 1.29 | 8.18 ± 1.66 | <0.001 |
| MELD score | 13.2 ± 5.95 | 17.9 ± 7.75 | 0.025 |
| QTc, ms | 462.64 ± 46.02 | 472.25 ± 46.19 | 0.659 |
| Echocardiographic data | | | |
| ESV, mL | 31.69 ± 18.57 | 45.51 ± 41.44 | 0.417 |
| EDV, mL | 69.96 ± 30.23 | 80.85 ± 44.64 | 0.565 |
| LVEF, % | 55.87 ± 11.72 | 51.59 ± 13.85 | 0.276 |
| E, cm/s | 85.26 ± 27.66 | 74.05 ± 27.23 | 0.219 |
| A, cm/s | 87.82 ± 26.16 | 82.65 ± 28.01 | 0.536 |
| Septal e′, cm/s | 6.13 ± 2.08 | 4.53 ± 2.14 | 0.116 |
| Septal E/e′ ratio | 16.49 ± 15.68 | 13.32 ± 4.54 | 0.557 |
| E/A ratio | 0.99 ± 0.55 | 0.93 ± 0.60 | 0.509 |
| RVSP, mmHg | 36.99 ± 15.69 | 42.17 ± 16.00 | 0.189 |
| DT, ms | 202.17 ± 107.91 | 218.18 ± 87.39 | 0.458 |
| ACEI/ARBs | 38 (41.3) | 2 (18.2) | 0.137 |
| NSBBs[a] | 11 (12.0) | 3 (27.3) | 0.161 |
| Statin | 17 (18.5) | 0 (0.0%) | 0.119 |
| Complications of cirrhosis | | | |
| Hepatic encephalopathy | 8 (8.7) | 0 (0.0) | 0.309 |
| Variceal bleeding | 4 (4.3) | 0 (0.0) | 1.000 |
| SBP | 3 (3.3) | 2 (18.2) | 0.087 |
| Acute kidney injury[b] | 30 (36.1) | 5 (50.0) | 0.393 |

The data are expressed as mean ± standard deviation or number (%). Pulmonary comorbidities included chronic obstructive pulmonary disease or asthma. Renal comorbidities included chronic kidney disease or end-stage renal disease. Neurologic comorbidities included cerebral vascular accidents. A = atrial (late) diastolic filling velocity; ACEI =angiotensin-converting enzyme inhibitors; ALBI = albumin-bilirubin; ARBs = angiotensin II receptor antagonist; Cr = creatinine; DT = early wave deceleration time; E = peak early filling velocity; e′ = early diastolic mitral annular velocity; E/A = ratio of early and late diastolic velocity; E/e′ ratio = ratio of early diastolic velocity to peak early diastolic mitral annular velocity; EDV = end-diastolic volume; ESV = end-systolic volume; INR = international normalized ratio; LVEF = left ventricle ejection fraction; MELD = model for end-stage liver disease; NSBBs = nonselective β-adrenergic blocker; QTc = corrected QT interval; RVSP = right ventricular systolic pressure; SBP = spontaneous bacterial peritonitis; TB = total bilirubin.

[a]NSBBs include propranolol or carvedilol.

[b]Exclude patients with end stage renal disease who received hemodialysis or peritoneal dialysis.

**Table 2**

**Cox's regression model of predictors for 1-year mortality in cirrhotic patients**

| Predictors | HR | 95% CI | *p* |
|---|---|---|---|
| Albumin | 8.46 | 0.56-127.59 | 0.123 |
| ALBI score | 9.30 | 0.51- 169.01 | 0.132 |
| Child-Pugh score | 1.99 | 1.04- 3.80 | 0.037 |
| MELD score | 1.01 | 0.89- 1.14 | 0.940 |
| Presence of ascites | 1.55 | 0.38- 6.26 | 0.549 |

ALBI = albumin-bilirubin; CI = confidence interval; HR = hazard ratio; MELD = model for end-stage liver disease.

serum Cr > 1.5 mg/dL, TB > 2 mg/dL, and septal E/e' remained significant for predicting the development of AKI in 1 year.

When only patients with serum Cr < 1.5 mg/dL were analyzed (Table 5), the baseline biochemical feature and severity of liver disease were similar. However, an increased atrial filling velocity and a lower E/A ratio were observed in patients with AKI events. Multivariate Cox hazard regression analysis (Table 6) revealed that A (cm/s) and ALBI score were the significant predictors of AKI in 1 year of follow-up.

Among patients who met the criteria of cirrhotic cardiomyopathy, 24 patients met the criteria of resting ejection fraction<55%, 25 patients met the criteria of E/A ration<1, and 19 patients met the criteria of deceleration time >200 ms. Finally, a total of 48 patients met the criteria of cirrhotic cardiomyopathy. Table 7 demonstrates the clinical outcomes of patients without (n = 21) or with cirrhotic cardiomyopathy (n = 48) at 1 year of follow-up after excluding those with coronary artery disease. Patients with the diagnosis of cirrhotic cardiomyopathy demonstrated lower LVEF, higher A (cm/s), higher E/A ratio, and longer DT (ms) than those without cirrhotic cardiomyopathy. Nevertheless, the cirrhosis-related complications and 1-year mortality rate were similar in both groups.

## 4. DISCUSSION

Cardiac dysfunction in liver cirrhosis is associated with poor survival and the development of cirrhosis-related complications. Therefore, some studies have investigated the correlation of echocardiographic parameters and patient outcomes, with diastolic dysfunction being the most evident factor for predicting outcomes.[1,2,5,22] Nevertheless, these studies showed discordant results on echocardiography in predicting outcomes.[11,23] In the present study, we found that there was no association between echocardiographic parameters and the occurrence of death at 1-year follow-up. Child-Pugh score was the only independent predictor for mortality at 1 year. Notably, an increased atrial filling velocity and higher ALBI scores helped in predicting the development of AKI among cirrhotic patients with serum Cr < 1.5 mg/dL. Our findings suggest a potential role of echocardiography and ALBI score in predicting AKI, which may be helpful in clinical practice to prevent adverse kidney events by ways of closely following up and avoidance of nephrotoxic drugs in these patients.

The predictive role of echocardiographic parameters on type 1 HRS has been addressed previously[1]. Several studies have shown that patients with an increased left atrial (LA) dimension, a higher E/e′ ratio or the presence of diastolic dysfunction on echocardiography were associated with poor survival.[1,2,5,6,22] However, other studies showed that the echocardiographic parameters were not associated with mortality and the only independent predicting factor for mortality was the Child-Pugh score or MELD score.[11,23] Possible reasons for these discrepancies between these studies include different enroll criteria,

**Table 3**

**Comparison of demographic, biochemical, and echocardiographic characteristics between those who did not develop AKI and who developed AKI at 1 year of follow-up in cirrhotic patients[a]**

| Variables | Without AKI (n = 58) | With AKI (n = 35) | *p* |
|---|---|---|---|
| Age, y | 67.38 ± 14.56 | 69.49 ± 15.94 | 0.357 |
| Male | 44 (75.9) | 25 (71.4) | 0.636 |
| Mean arterial pressure, mmHg | 90.93 ± 14.34 | 87.59 ± 11.68 | 0.337 |
| Cause of cirrhosis (%) | | | |
| Viral | 40 (69.0) | 24 (68.6) | 0.968 |
| Alcohol | 6 (10.3) | 4 (11.4) | 0.870 |
| Other | 12 (20.7) | 7 (20.0) | 0.936 |
| Laboratory | | | |
| Platelet, 1000/μL | 142.33 ± 170.71 | 121.89 ± 69.00 | 0.968 |
| Sodium, mEq/L | 133.14 ± 25.77 | 138.71 ± 4.44 | 0.247 |
| Cr, mg/dL | 1.35 ± 0.92 | 1.84 ± 1.24 | 0.013 |
| TB, mg/dL | 1.31 ± 2.73 | 2.43 ± 4.69 | 0.027 |
| Albumin, g/dL | 3.39 ± 0.68 | 3.25 ± 0.50 | 0.428 |
| INR | 1.11 ± 0.28 | 1.20 ± 0.26 | 0.263 |
| Comorbidity | | | |
| Diabetes | 22 (37.9) | 14 (42.9) | 0.638 |
| Pulmonary | 10 (17.2) | 5 (14.3) | 0.707 |
| Hypertension | 40 (69.0) | 24 (68.6) | 0.968 |
| Congestive heart failure | 8 (13.8) | 5 (14.3) | 0.947 |
| Coronary artery disease | 17 (29.3) | 6 (17.1) | 0.188 |
| Renal | 5 (8.6) | 10 (28.6) | 0.011 |
| Neurologic | 3 (5.2) | 4 (11.4) | 0.419 |
| Malignancy | 21 (36.2) | 16 (45.7) | 0.364 |
| Cirrhotic cardiomyopathy | 37 (63.8) | 24 (68.6) | 0.638 |
| Presence of ascites | 13 (22.4) | 6 (17.1) | 0.541 |
| ALBI score | -2.16 ± 0.59 | -1.89 ± 0.53 | 0.072 |
| Child-Pugh score | 6.19 ± 1.47 | 6.51 ± 1.42 | 0.201 |
| MELD score | 11.59 ± 5.36 | 15.03 ± 6.59 | 0.003 |
| QTc, ms | 458.04 ± 50.69 | 469.71 ± 41.59 | 0.214 |
| Echocardiographic data | | | |
| ESV, mL | 34.60 ± 26.2 | 34.50 ± 19.56 | 0.427 |
| EDV, mL | 71.55 ± 36.29 | 75.64 ± 27.63 | 0.384 |
| LVEF, % | 54.92 ± 13.61 | 56.46 ± 10.00 | 0.620 |
| E, cm/s | 77.13 ± 23.08 | 86.15 ± 29.55 | 0.141 |
| A, cm/s | 77.46 ± 19.95 | 106.07 ± 26.33 | <0.001 |
| Septal e′, cm/s | 6.18 ± 2.01 | 5.44 ± 2.33 | 0.041 |
| Septal E/e′ ratio | 12.22 ± 4.20 | 20.54 ± 23.16 | 0.018 |
| E/A ratio | 1.07 ± 0.52 | 0.748 ± 0.3234 | 0.006 |
| RVSP, mmHg | 35.90 ± 17.37 | 38.35 ± 13.97 | 0.165 |
| DT, ms | 194.83 ± 98.09 | 217.14 ± 122.44 | 0.459 |
| ACEI/ARBs | 26 (44.8) | 9 (25.7) | 0.065 |
| NSBBs | 8 (13.8) | 5 (14.3) | 0.947 |
| Statin | 12 (20.7) | 3 (8.6) | 0.124 |
| Complications of cirrhosis | | | |
| Hepatic encephalopathy | 2 (3.4) | 3 (8.6) | 0.361 |
| Variceal bleeding | 3 (5.2) | 1 (2.9) | 1.000 |
| SBP | 4 (6.9) | 1 (2.9) | 0.647 |

The data are expressed as mean ± standard deviation or number (%). Pulmonary comorbidities included chronic obstructive pulmonary disease or asthma. Renal comorbidities included chronic kidney disease or end-stage renal disease. Neurologic comorbidities included cerebral vascular accidents.

A = atrial (late) diastolic filling velocity; ACEI =angiotensin-converting enzyme inhibitors; AKI = acute kidney injury; ALBI = albumin-bilirubin; ARBs = angiotensin II receptor antagonist; Cr = creatinine; DT = early wave deceleration time; E = peak early filling velocity; e′ = early diastolic mitral annular velocity; E/A = ratio of early and late diastolic velocity; E/e′ ratio = ratio of early diastolic velocity to peak early diastolic mitral annular velocity; EDV = end-diastolic volume; ESV = end-systolic volume; INR = international normalized ratio; LVEF = left ventricle ejection fraction; MELD = model for end-stage liver disease; NSBBs = nonselective β-adrenergic blocker; QTc = corrected QT interval; RVSP = right ventricular systolic pressure; SBP = spontaneous bacterial peritonitis; TB = total bilirubin..

[a]Exclude patients with end-stage renal disease who received hemodialysis or peritoneal dialysis

different follow-up time, and differences in the cause of cirrhosis. In the present study, we found that the baseline echocardiographic data did not differ between survivors and nonsurvivors at 1-year follow-up. Multivariate analysis revealed that only Child-Pugh score could predict 1-year mortality in cirrhosis. Moreover, there was no difference in 1-year mortality between patients with and without the diagnosis of cirrhotic cardiomyopathy, which suggests that cardiovascular dysfunction is not directly related to 1-year mortality in these patients.

Regarding the development of AKI, previous studies have aimed at identifying risk factors for AKI in cirrhosis. It has been reported that serum cystatin C levels and prior AKI events are independent predictors for the development of AKI and the risk of subsequent AKI rises with an increase in the number of AKI episodes.[24] Among cirrhotic patients with ascites, the severity of ascites is also a significant predictor for the occurrence of AKI.[25] On cardiovascular parameters, cardiac index and E/e′ were potential predictors for type 1 HRS.[1,3,5] In Fernández's study, primary prophylaxis of SBP with Norfloxacin in patients with advanced liver failure (Child-Pugh scores ≥ 9 points with TB ≥ 3 mg/dL) or impaired renal function (Cr ≥ 1.2 mg/dL, blood urea nitrogen ≥ 25 mg/dL, or sodium level ≤ 130 mEq/L) reduces the incidence of SBP and delays the development of HRS.[26] In this study, baseline serum Cr > 1.5 mg/dL, TB > 2 mg/dL, and a higher E/e′ ratio were independent predictors for AKI. The predictive role of these factors was not masked by MELD score, a scoring system in which renal function was included. Increased serum levels of TB and creatinine are known risk factors for the development of SBP, which is a strong precipitating factor of HRS.[26–28] Although the cut-off value of serum bilirubin and creatinine level was different between our study and Fernández's study, future prospective study investigating the effect of prophylactic antibiotic treatment for patients at high risk of developing AKI is anticipated.

On the other hand, Cullaro et al.[29] demonstrated that the risk of AKI in cirrhosis increases with the increments in serum creatinine levels even in those with "clinically normal" baseline creatinine levels. To further evaluate potential echocardiographic parameters in predicting AKI in patients with low creatinine levels, we identified 61 patients with serum Cr < 1.5 mg/dL. We further found that an increased atrial filling velocity and higher ALBI scores were associated with the development of AKI. Atrial filling velocity reflects the pressure gradient between left atrium and ventricle during the phase of late diastole, which is affected by LV compliance and LA contractile function,[30] As a result, trial filling velocity has been used to be one of the echocardiographic parameters for LA systolic function assessment.[31] The finding in our study indicates that impaired atrial contraction might be a risk factor for developing AKI in cirrhotic patients with serum Cr < 1.5 mg/dL. Moreover, ALBI score, a simple score which was initially used to evaluate the severity of liver dysfunction in patients with hepatocellular carcinoma,[32,33] has been recently discussed to have a predictive role in outcomes of cirrhotic patients.[34–37] However, no study to date has evaluated the role of ALBI score in AKI occurrence in cirrhotics. In our study, we found that ALBI score was a strong predictor for the development of AKI in patients with Cr < 1.5 mg/dL. Further prospective studies with large sample size are needed to validate the clinical significance of echocardiographic parameters and ALBI scores in AKI occurrence among cirrhotic patients.

This study has some limitations. First, this was a retrospective, observational study using data from a single medical center, leaving the analysis susceptible to selection bias or other unconsidered variables. Second, we did not excluded patients taking β-blockers or other drugs that may interfere with heart function. Third, because of the missing data, several important measurements, such as LA volume/size, lateral e′, and cardiac index, which are

**Table 4**

**Cox's regression model of predictors for acute kidney injury in 1 year in cirrhotic patients**

| | Model 1 (dropping MELD score) | | | Model 2 (including MELD score) | | |
|---|---|---|---|---|---|---|
| **Predictors** | **HR** | **95% CI** | ***p*** | **HR** | **95% CI** | ***p*** |
| Cr > 1.5 mg/dL | 6.26 | 1.62-24.17 | 0.011 | 12.57 | 1.21-131.03 | 0.034 |
| TB > 2 mg/dL | 4.40 | 1.11-17.54 | 0.036 | 4.59 | 1.12-18.85 | 0.034 |
| ALBI score | 2.87 | 0.78-10.50 | 0.111 | 4.21 | 0.75-23.48 | 0.101 |
| A, cm/s | 1.01 | 0.98-1.04 | 0.347 | 1.01 | 0.99-1.04 | 0.298 |
| Septal e′ | 1.03 | 0.69-1.54 | 0.884 | 0..97 | 0.63-1.50 | 0.894 |
| E/A < 1 | 2.78 | 0.54-14.22 | 0.220 | 2.45 | 0.44-13.56 | 0.303 |
| Septal E/e′ | 1.14 | 1.03-1.27 | 0.011 | 1.14 | 1.03-1.27 | 0.010 |
| MELD score | | | | 0.02 | 0.74-1.15 | 0.480 |

A = atrial (late) diastolic filling velocity; ALBI = albumin-bilirubin; CI = confidence interval; Cr = creatinine; e′ = early diastolic mitral annular velocity; E/A = ratio of early and late diastolic velocity; E/e' ratio = ratio of early diastolic velocity to peak early diastolic mitral annular velocity; HR = hazard ratio; MELD = model for end-stage liver disease; TB = total bilirubin.

**Table 5**

**Comparison of demographic, biochemical, and echocardiographic characteristics between those who developed AKI and who did not develop AKI at 1 year of follow-up in cirrhotic patients with baseline Cr < 1.5 mg/dL**

| **Variables** | **Without AKI (n = 44)** | **With AKI (n = 17)** | ***p*** |
|---|---|---|---|
| Age, y | 65.32 ± 14.95 | 69.47 ± 9.53 | 0.489 |
| Male | 34 (77.3) | 9 (52.9) | 0.062 |
| Mean arterial pressure, mmHg | 91.72 ± 13.06 | 85.64 ± 11.9 | 0.113 |
| Laboratory | | | |
| Platelet, 1000/μL | 115.55 ± 71.84 | 111.24 ± 56.14 | 0.904 |
| Sodium, mEq/L | 132.05 ± 29.46 | 138.35 ± 4.34 | 0.765 |
| Cr, mg/dL | 0.95 ± 0.23 | 0.98 ± 0.20 | 0.546 |
| TB, mg/dL | 1.13 ± 0.62 | 1.60 ± 1.18 | 0.292 |
| Albumin, g/dL | 3.57 ± 0.64 | 3.36 ± 0.51 | 0.337 |
| INR | 1.14 ± 0.12 | 1.20 ± 0.17 | 0.189 |
| Comorbidity | | | |
| Diabetes | 15 (34.1) | 8 (47.1) | 0.349 |
| Pulmonary | 6 (13.6) | 2 (11.8) | 0.846 |
| Hypertension | 30 (68.2) | 11 (64.7) | 0.795 |
| Congestive heart failure | 4 (9.1) | 1 (5.9) | 1.000 |
| Coronary artery disease | 12 (27.3) | 3 (17.6) | 0.434 |
| Neurologic | 3 (6.8) | 1 (5.9) | 1.000 |
| Malignancy | 16 (36.4) | 7 (41.2) | 0.728 |
| Cirrhotic cardiomyopathy | 2 (59.1) | 10 (58.8) | 0.985 |
| Presence of ascites | 8 (18.2) | 3 (17.6) | 0.961 |
| ALBI score | -2.23 ± 0.59 | -1.96 ± 0.54 | 0.149 |
| Child-Pugh score | 5.84 ± 1.10 | 6.29 ± 1.31 | 0.178 |
| MELD score | 9.32 ± 2.77 | 11.06 ± 4.09 | 0.051 |
| QTc, ms | 459.14 ± 50.84 | 463.7 ± 39.17 | 0.689 |
| ACEI/ARBs | 17 (38.6) | 4 (23.5) | 0.266 |
| NSBBs | 6 (13.6) | 2 (11.8) | 0.846 |
| Statin | 10 (22.7)) | 1 (5.9) | 0.125 |
| Echocardiographic data | | | |
| ESV, mL | 33.48 ± 21.97 | 27.31 ± 9.12 | 0.723 |
| EDV, mL | 3.57 ± 0.64 | 3.36 ± 0.51 | 0.583 |
| LVEF, % | 56.84 ± 13.20 | 58.00 ± 8.91 | 0.778 |
| E, cm/s | 75.83 ± 21.93 | 86.33 ± 27.45 | 0.191 |
| A, cm/s | 78.36 ± 19.00 | 98.32 ± 23.99 | 0.042 |
| Septal e′, cm/s | 6.13 ± 1.59 | 5.89 ± 2.73 | 0.376 |
| Septal E/e′ ratio | 12.37 ± 4.20 | 16.03 ± 8.21 | 0.132 |
| E/A ratio | 1.04 ± 0.46 | 0.72 ± 0.33 | 0.023 |
| RVSP, mmHg | 32.60 ± 14.32 | 41.39 ± 16.59 | 0.065 |
| DT, ms | 230.00 ± 56.39 | 275.00 ± 112.55 | 0.173 |

The data are expressed as mean ± standard deviation or number (%).

A = atrial (late) diastolic filling velocity; ACEI =angiotensin-converting enzyme inhibitors; AKI = acute kidney injury; ALBI = albumin-bilirubin; ARBs = angiotensin II receptor antagonist; Cr = creatinine; DT = early wave deceleration time; E = peak early filling velocity; e′ = early diastolic mitral annular velocity; E/A = ratio of early and late diastolic velocity; E/e′ ratio = ratio of early diastolic velocity to peak early diastolic mitral annular velocity; EDV = end-diastolic volume; ESV = end-systolic volume; INR = international normalized ratio; LVEF = left ventricle ejection fraction; MELD = model for end-stage liver disease; NSBBs = nonselective β-adrenergic blocker; QTc = corrected QT interval; RVSP = right ventricular systolic pressure; SBP = spontaneous bacterial peritonitis; TB = total bilirubin

**Table 6**

**Cox's regression model of predictors for acute kidney injury in 1 year in cirrhotic patients with baseline creatinine < 1.5 mg/dL**

| Predictors | HR | 95% CI | p |
|---|---|---|---|
| ALBI score | 3.263 | 1.29-8.27 | 0.013 |
| A, cm/s | 1.03 | 1.01- 106 | 0.004 |
| E/A < 1 | 1.60 | 0.41- 6.29 | 0.502 |
| MELD score | 1.08 | 0.99-1.18 | 0.097 |

A = atrial (late) diastolic filling velocity; ALBI = albumin-bilirubin; CI = confidence interval; E/A = ratio of early and late diastolic velocity; HR = hazard ratio; MELD = model for end-stage liver disease.

**Table 7**

**Comparison of demographic, echocardiographic characteristics, and complications in patients without and with cirrhotic cardiomyopathy at 1 year of follow-up after excluding those with coronary artery disease**

| Variables | Without cardiomyopathy (n = 28) | With cardiomyopathy (n = 48) | p |
|---|---|---|---|
| Age, y | 69.18 ± 12.10 | 69.40 ± 15.69 | 0.747 |
| Male | 20 (71.4) | 35 (72.9) | 0.889 |
| Mean arterial pressure, mmHg | 89.29 ± 14.03 | 86.85 ± 12.32 | 0.620 |
| Laboratory | | | |
| Platelet, 1000/μL | 121.64 ± 80.47 | 140.44 ± 178.72 | 0.678 |
| Sodium, mEq/L | 132.82 ± 26.44 | 138.65 ± 4.517 | 0.361 |
| Cr, mg/dL | 1.13 ± 0 .41 | 1.82 ± 1.60 | 0.134 |
| TB, mg/dL | 2.12 ± 5.03 | 1.80 ± 3.32 | 0.827 |
| Albumin, g/dL | 3.40 ± 0.67 | 3.18 ± 0.55 | 0.223 |
| INR | 1.21 ± 0.27 | 1.18 ± 0.19 | 0.575 |
| Presence of ascites | 4 (14.3) | 11 (22.9) | 0.362 |
| ALBI score | -2.10 ± 0.62 | -1.92 ± 0.55 | 0.283 |
| Child-Pugh score | 6.14 ± 1.24 | 6.63 ± 1.58 | 0.209 |
| MELD score | 11.71 ± 5.72 | 14.81 ± 6.4 | 0.028 |
| QTc, ms | 472.43 ± 59.63 | 461.45 ± 41.26 | 0.710 |
| Echocardiographic data | | | |
| ESV, mL | 22.40 ± 7.84 | 31.90 ± 18.12 | 0.029 |
| EDV, mL | 56.25 ± 22.72 | 68.59 ± 26.21 | 0.217 |
| LVEF, % | 63.75 ± 6.71 | 52.42 ± 12.58 | <0.001 |
| E, cm/s | 91.46 ± 26.01 | 80.84 ± 29.67 | 0.157 |
| A, cm/s | 66.91 ± 16.26 | 94.72 ± 24.88 | 0.004 |
| Septal e′, cm/s | 7.51 ± 2.27 | 5.711 ± 2.00 | 0.009 |
| Septal E/e′ ratio | 13.57 ± 7.37 | 18.06 ± 20.35 | 0.137 |
| E/A ratio | 1.47 ± 0.42 | 0.82 ± 0.36 | <0.001 |
| RVSP, mmHg | 36.20 ± 11.67 | 40.80 ± 17.16 | 0.709 |
| DT, ms | 204.35 ±20.85 | 244.19 ± 88.11 | 0.007 |
| ACEI/ARBs | 8 (28.6) | 17 (35.4) | 0.540 |
| NSBBs | 3 (10.7) | 7 (14.6) | 0.630 |
| Statin | 2 (7.1) | 4 (8.3) | 1.000 |
| Complications of cirrhosis | | | |
| Hepatic encephalopathy | 1 (3.6) | 5 (10.4) | 0.404 |
| Variceal bleeding | 2 (7.1) | 1 (2.1) | 0.551 |
| SBP | 2 (7.1) | 2 (4.2) | 0.582 |
| Acute kidney injury[a] | 10 (37.0) | 19 (44.2) | 0.554 |
| One-year mortality | 2 (7.1) | 6 (12.5) | 0.463 |

The data are expressed as mean ± standard deviation or number (%).

A = atrial (late) diastolic filling velocity; ACEI =angiotensin-converting enzyme inhibitors; AKI = acute kidney injury; ALBI = albumin-bilirubin; ARBs = angiotensin II receptor antagonist; Cr = creatinine; DT = early wave deceleration time; E = peak early filling velocity; e′ = early diastolic mitral annular velocity; E/A = ratio of early and late diastolic velocity; E/e′ ratio = ratio of early diastolic velocity to peak early diastolic mitral annular velocity; EDV = end-diastolic volume; ESV = end-systolic volume; INR = international normalized ratio; LVEF = left ventricle ejection fraction; MELD = model for end-stage liver disease; NSBBs = nonselective β-adrenergic blocker; QTc = corrected QT interval; RVSP = right ventricular systolic pressure; SBP = spontaneous bacterial peritonitis; TB = total bilirubin.

[a] Exclude patients with end-stage renal disease who received hemodialysis or peritoneal dialysis.

important in deciding the severity of LV diastolic dysfunction[30] and the severity of cirrhotic cardiomyopathy, have been omitted from our study. Finally, the small case number was another limitation in this study, and caution must be taken in interpreting data.

In conclusion, in cirrhotic patients, mortality within 1 year was mainly determined by the underlying severity of liver disease. Echocardiographic parameters could not predict mortality in our study. Baseline serum Cr > 1.5 mg/dL, TB > 2 mg/dL, and a higher E/e′ ratio were independent predictors for AKI occurrence in cirrhotic patients. Furthermore, in cirrhotic patients with serum Cr < 1.5 mg/dL, an increased atrial filling velocity and higher ALBI scores predicted AKI development. Our study suggests that echocardiographic assessment and ALBI score evaluation in cirrhotic patients may help to identify patients at high risk of developing AKI, especially those with baseline serum Cr < 1.5 mg/dL. Moreover, we remind physicians to closely monitor renal function in such patients to avoid preventable kidney damage.

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