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Model for End-Stage Liver Disease Predicts Mortality for Tricuspid Valve Surgery

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Abstract

Background—Patients undergoing tricuspid valve surgery have a mortality of 9.8%, which is higher than expected given the complexity of the procedure. Despite liver dysfunction seen in many patients with tricuspid disease, no existing risk model accounts for this. The Model for End-Stage Liver Disease (MELD) score accurately predicts mortality for abdominal surgery. The objective of this study was to determine if MELD could accurately predict mortality after tricuspid valve surgery and compare it to existing risk models.

Methods—From 1994 to 2008, 168 patients (mean age, 61 ± 14 years; male = 72, female = 96) underwent tricuspid repair (n = 156) or replacement (n = 12). Concomitant operations were performed in 87% (146 of 168). Patients with history of cirrhosis or MELD score 15 or greater ($MELD = 3.8 * LN [total\ bilirubin] + 11.2 * \log\ normal [international\ normalized\ ratio] + 9.6 * \log\ normal [creatinine] + 6.4$) were compared with patients without liver disease or MELD score less than 15. Preoperative risk, intraoperative findings, and complications including operative mortality were evaluated. Statistical analyses were performed using χ^2 , Fisher's exact test, and area under the curve (AUC) analyses.

Results—Patients with a history of liver disease or MELD score of 15 or greater had significantly higher mortality (18.9% [7 of 37] versus 6.1% [8 of 131], $p = 0.024$). To further characterize the effect of MELD, patients were stratified by MELD alone. No major differences in demographics or operation were identified between groups. Mortality increased as MELD score increased, especially when MELD score of 15 or greater ($p = 0.0015$). A MELD score less than 10, 10 to 14.9, 15 to 19.9, and more than 20 was associated with operative mortality of 1.9%, 6.8%, 27.3%, and 30.8%, respectively. By multivariate analysis, MELD score of 15 or greater remained strongly associated with mortality ($p = 0.0021$). The MELD score predicted mortality (AUC = 0.78) as well as the European System for Cardiac Operative Risk Evaluation logistic risk calculator (AUC = 0.78, $p = 0.96$).

Conclusions—The MELD score predicts mortality in patients undergoing tricuspid valve surgery and offers a simple and effective method of risk stratification in these patients.

According to The Society of Thoracic Surgeons (STS) database, patients undergoing tricuspid valve surgery have an operative mortality of 9.8% [1]. Large centers performing tricuspid valve surgery report an operative mortality of 8% to 13.9% [2, 3]. Despite the ease of tricuspid valve repair, tricuspid disease is associated with significant comorbidities

including pulmonary hypertension and liver dysfunction. Secondary liver dysfunction is thought to occur as a result of passive hepatic congestion from tricuspid disease.

Risk scoring systems have been used to compare patients' risks, to assess performance measures, and to audit quality outcomes [4]. Existing risk assessment tools in cardiac surgery, including the STS risk prediction model and the European System for Cardiac Operative Risk Evaluation (EuroSCORE), account for pulmonary hypertension but do not account for liver dysfunction. Although liver disease is a cited risk factor for mortality and complications after cardiac surgery [5, 6], there is no method to adjust for liver disease in the current risk models.

The Model for End-Stage Liver Disease (MELD) score is used to stratify patients awaiting liver transplantation [7], and its calculation is dependent on three variables: international normalized ratio (INR), total bilirubin, and creatinine. Although designed for patients with primary liver disease, MELD has been shown to predict mortality for patients with liver dysfunction undergoing nontransplant abdominal surgery [8–10]. The MELD score has been seldom utilized to assess the risk of cardiac surgery in patients with liver disease and, in particular, has never been utilized to stratify risk in patients with tricuspid valve disease. The primary objective of this study was to determine if liver disease affects outcomes with tricuspid valve surgery. Further, we hypothesized that MELD could be used to stratify patients undergoing tricuspid surgery and that MELD could predict mortality as well as EuroSCORE.

Patients and Methods

Approval for this investigation was obtained by the Human Investigation Committee of the University of Virginia Health System, including a waiver for the need to obtain patient consent.

All patients undergoing tricuspid valve operation at our institution are entered prospectively into the STS database. A retrospective review was performed of all tricuspid valve operations from January 1994 to March 2008. A total of 168 patients (mean age, 61 ± 14 years; male = 72, female = 96) underwent tricuspid valve operation.

To examine the significance of liver disease in patients undergoing tricuspid valve surgery, patients were separated based on whether or not they had significant liver disease as defined by (1) history of cirrhosis, or (2) preoperative MELD score of 15 or more.

The MELD score is defined by the equation: $MELD = 3.8 * LN(\text{total bilirubin}) + 11.2 * LN(\text{INR}) + 9.6 * LN(\text{creatinine}) + 6.4$, where LN = log normal, INR = international normalized ratio.

Demographic, preoperative comorbidities, and operative variables were compared between the two groups. Preoperative renal failure was defined by creatinine greater than 2.0 mg/dL according to the STS database. The INR utilized for the MELD analysis was drawn on the morning of surgery. A total of 74 patients (44%) were on coumadin preoperatively, most often for atrial fibrillation. Elective patients had their coumadin held at least 5 days preoperatively, allowing for recovery of their INR. Urgent and emergent cases had reversal of their coumadin with fresh frozen plasma. Outcomes measured included operative mortality and perioperative complications.

To further characterize the effect of preoperative MELD in patients undergoing tricuspid valve surgery, we evaluated the effect of preoperative MELD on outcome. Because testing preoperative liver function tests (total bilirubin) is not routinely collected with STS data,

preoperative MELD was able to be calculated in 72.6% (122 of 168) of all patients. Patients were stratified by their preoperative MELD score into four groups: less than 10, 10 to 14.9, 15 to 19.9, and 20 or more. Preoperative variables, intraoperative findings, and complications including operative mortality were evaluated. Univariate and multivariate analyses were performed to identify risk factors related to mortality.

Finally, preoperative MELD was assessed as a risk stratification tool. A logistic EuroSCORE was calculated on all patients and was compared with MELD score. The STS model does not calculate a predicted risk for patients undergoing tricuspid valve surgery. Therefore, it could not be used for comparison to MELD or EuroSCORE in this group of patients.

Statistical Analysis

Patient demographics, preoperative factors, intraoperative factors, and outcomes were first compared using univariate techniques. Continuous variables were compared using the Wilcoxon two-sample test for cases where only two groups were being compared, higher order comparisons were performed with the Kruskal-Wallis test. Categorical variables were compared with the χ^2 test or Fisher's exact test, where appropriate. The capabilities of MELD to predict 30-day mortality were compared with the EuroSCORE logistic model by calculating the receiver operating characteristic area under the curve (AUC) for each and comparing them using techniques described by DeLong and colleagues [11]. This analysis was performed on all patients with a preoperative MELD score.

Lastly, a multivariate logistic regression analysis was performed examining the outcome of operative (30-day) mortality. Variables entered into the model included those risk factors with significant or near significant ($p < 0.1$) influence on mortality by univariate analysis. Data manipulation and analysis were performed using SAS 9.1.3 (SAS Institute, Cary, NC).

Results

Tricuspid valve repair ($n = 156$) was more commonly performed than replacement ($n = 12$, 92.9% versus 7.1%, $p < 0.0001$). Concomitant operations, performed in 85.7% (134 of 168), included coronary artery bypass graft surgery ($n = 32$), mitral valve replacement ($n = 76$), mitral valve repair ($n = 14$), and aortic valve replacement ($n = 42$). Operative mortality was 8.9% (15 of 168). Stroke occurred in 1.8% ($n = 3$), renal failure in 16% ($n = 27$), multisystem organ failure in 5.3% ($n = 9$), and prolonged ventilation (> 24 hours) in 26.8% ($n = 45$).

Effect of Liver Disease on Tricuspid Valve Surgery

Patients with significant liver disease (defined by a history of cirrhosis or MELD score of 15 or greater, or both) comprised 22.0% ($n = 37$) of patients undergoing tricuspid surgery. Of these, 19 had MELD score of 15 or greater and the remainder were included based on history of cirrhosis. The etiology of liver disease for these patients included 13 patients (35%) with alcoholic liver disease, 4 patients (11%) with hepatitis B, and 5 patients (14%) with hepatitis C (Table 1). Compared with patients without significant liver disease, patients with liver disease more often were younger, male, and had a diagnosis of endocarditis. Patients with significant liver disease were more likely to have preoperative renal failure (51.4% versus 13.0%, $p < 0.0001$). Other preoperative risk factors were no different including age, ejection fraction, congestive heart failure.

The number of patients undergoing concomitant operations was similar between the two groups. Patients with liver disease were less likely to undergo concomitant coronary artery

bypass graft surgery (5.4% versus 22.9%, $p = 0.017$). Tricuspid valve replacement and cardiopulmonary bypass times were similar between groups.

Patients with liver disease had worse outcomes. Postoperative sepsis, gastrointestinal complications, and multisystem organ failure were significantly more common in patients with liver disease. The incidence of patients with new-onset renal failure requiring dialysis was also higher among patients with liver disease. Importantly, patients with liver disease had worse a mortality rate than did patients without liver disease (18.9% versus 6.1%, $p = 0.024$).

Effect of MELD on Tricuspid Valve Surgery

Patients with preoperative MELD were stratified by MELD and compared (122 of 168 patients). Preoperative and intraoperative variables are listed in Table 2. Patients with higher MELD were more likely to have endocarditis ($p = 0.021$) and peripheral vascular disease ($p < 0.0005$). Other preoperative variables and concomitant procedures were similar across the groups. Cardiopulmonary bypass time increased as MELD increased.

Multisystem organ failure was more common in patients with worse MELD scores ($p = 0.019$). Multisystem organ failure occurred in 18.2% of patients with MELD score 15 to 19.9, and in 23.1% of patients with MELD score 20 or higher. Mortality increased with increasing MELD score (Fig 1). Patients with MELD less than 10 and 10 to 14.9 had an operative mortality of 1.9% and 6.8%, respectively. In patients with MELD 15 to 19.9 and greater than 20, operative mortality increased significantly to 27.3% and 30.8%, respectively ($p = 0.0015$). A MELD score of 15 or higher translated to worse mortality (29.2% [7 of 24]) compared with a MELD score less than 15 (4.1% [4 of 98], $p < 0.0001$). For patients without preoperative MELD score, operative mortality was 8.7% (4 of 46), compared with 9.0% (11 of 122) for patients with preoperative MELD ($p =$ not significant).

Risk Factors Related to Mortality

A univariate analysis of all risk factors related to operative mortality was performed (Table 3). Variables noted to be different in patients with and without liver disease or in patients with worse MELD including age, sex, and endocarditis were no different between survivors or patients who died. Moreover, tricuspid valve replacement and concomitant mitral valve procedures were equivalent in survivors and patients who died. Only MELD score of 15 or higher ($p = 0.0017$) and renal failure ($p < 0.0001$) were more common among patients who died.

A multivariate logistic regression analysis was performed examining the outcome of operative mortality. Variables entered into the model included those risk factors with significant or near significant ($p < 0.1$) influence on 30-day mortality by univariate analysis (Table 3), including MELD score of 15 or higher, cerebrovascular disease, and peripheral vascular disease. Because renal insufficiency is measured as part of the MELD score, this was excluded from the model. The only independent predictor of operative mortality in this model was MELD score 15 or higher, with an odds ratio of 9.38 (95% confidence interval: 2.25 to 39, $p = 0.0021$). The model demonstrated good statistical performance with $R^2 = 0.10$ and c statistic = 0.85.

Comparison of MELD to EuroSCORE

A comparison of the receiver operating characteristic plots for the MELD score (AUC = 0.78) and the Euro-SCORE logistic model (AUC = 0.78) were similar ($p = 0.96$; Fig 2).

Comment

Accurate preoperative risk stratification is essential given the scrutiny of cardiac surgical outcomes. To date, no model in use accounts for liver disease in the stratification of patients undergoing cardiac surgery. Patients with tricuspid valve disease, in particular, have associated liver dysfunction. In the present study, we document worse mortality and complications in patients with liver dysfunction undergoing tricuspid valve surgery. Furthermore, there was a strong correlation between MELD score and operative mortality. Specifically, mortality and complication rates increased when the preoperative MELD score was 15 or higher. Moreover, MELD was equivalent to the more complex EuroSCORE in its predictive capacity in this group of patients. This suggests that MELD can be used as a simple predictive model in patients with severe tricuspid disease. To fully test this hypothesis, MELD must be validated in a different cohort of patients as a predictive tool. Because liver function tests including total bilirubin are not routinely collected in the STS database, many patients undergoing tricuspid valve surgery do not have these tests performed preoperatively.

Hepatic dysfunction is known risk factor for surgical candidates. Various risk assessment tools have been developed to stratify the degree of liver disease. The Childs-Turcotte-Pugh classification (CTP) was developed to assess the operative risk in patients undergoing portosystemic shunts [12, 13]. The CTP classification model subsequently became the leading assessment method of classify functional hepatic status. For surgical patients, the CTP model was extrapolated to predict postoperative outcomes in other patients with cirrhosis [14]. One inherent problem with the CTP classification system, however, was the inclusion of largely subjective parameters (such as presence of ascites, nutritional status, and degree of encephalopathy). Consequently, in 2000, a new risk assessment method was developed for patients with liver disease. The Mayo End-Stage Liver Disease score was originally developed to assess the functional liver status in patients undergoing transjugular intrahepatic portosystemic shunts [15]. Subsequently, the scoring system was renamed to the Model for End-Stage Liver Disease (MELD) when it was adopted by the United Network for Organ Sharing and utilized in the allocation of cadaveric livers [7, 16].

The MELD score has become the preferred risk assessment tool for cirrhosis in general surgical patients [8, 10, 17, 18]. Several groups have compared the CTP classification and MELD score in patients undergoing general surgical procedures [8–10]. A recent study concluded that a MELD score higher than 14 was a worse prognosticator than CTP class C for perioperative complications for intra-abdominal surgery [8]. Northup and colleagues [10] furthered these findings in 140 nontransplant surgical patients and demonstrated that, for the first time, MELD was predictive for operative mortality. In that study, mortality increased 1% to 2% for every MELD point. The CTP is subjective, whereas MELD is able to be calculated on three common blood tests. Moreover, MELD includes the effect of renal dysfunction, which is a significant comorbidity in patients with liver disease.

Liver disease is an important risk factor in patients undergoing cardiac surgery [5, 19, 20]. An association between tricuspid valve dysfunction and liver disease due to hepatic congestion has been well established [21, 22]. Suman and coworkers [18] demonstrated a strong correlation between CTP, MELD, and mortality (AUC = 0.84 and 0.87, respectively) in 44 patients primarily undergoing coronary artery bypass graft surgery. In this study, CTP score greater than 7 and MELD score greater than 13 were highly specific for mortality (92% and 89%, respectively). In contrast, Filsoufi and colleagues [20] concluded that CTP was superior to MELD score in predicting hospital mortality ($p = 0.02$ versus $p = 0.065$) in 27 cirrhotic patients undergoing cardiac surgery. Specifically, mortality rates were 10%, 18%, and 67% for CTP classes A, B, and C, respectively. The results of these two studies

provide conflicting results with respect to the predictive capacity of MELD score in cardiac surgery patients. Importantly, both studies analyzed small patient groups and did not have sufficient power to evaluate patients according to MELD score distribution.

Many patients with high MELD score had significant renal dysfunction. Preoperative renal disease is a well-documented risk factor in cardiac surgery and specifically in patients with tricuspid valve disease [23–25]. All existing risk calculators account for renal disease, although often as a categorical variable. Renal disease is a continuous variable affecting MELD score.

Several risk stratification schemes have been developed to predict mortality after cardiac surgery including STS Score, EuroSCORE, Parsonnet score, and the Cleveland Clinic model [26–31]. The EuroSCORE is a complex, risk stratification scheme that utilizes 17 patient-related, cardiac-related, and operation-related factors to calculate a predicted mortality rate and has gained popularity among European and Canadian surgeons [28]. Geissler and colleagues [32] compared six scoring systems used for risk stratification in 504 cardiac surgery patients and found that the EuroSCORE yielded the highest predictive value for mortality. Other recent comparisons of these models have supported the conclusion that EuroSCORE functions as a superior predictive model for risk stratification with nearly identical observed and expected mortality [32–34]. Although this scoring system appears to successfully predict postoperative mortality for the majority of cardiac surgery patients, it does not adjust for liver disease as a preoperative risk factor. Owing to the inherent multiorgan system effects of both hepatic dysfunction and cardiac surgery, a reliable predictive model of postoperative outcomes for patients with known liver diseases remains desirable. Furthermore, the EuroSCORE has not gained popularity in the United States because of the multiple variables required, including pulmonary artery pressure, which may necessitate right heart catheterization. The MELD score offers a simple method, requiring three common blood tests to calculate.

There are several limitations to this study. First, it is a retrospective study and has inherent biases. The total number of patients undergoing tricuspid surgery is admittedly small. A major limitation is in our definition of liver disease. Because liver function is not tested routinely, we defined liver disease as a history of cirrhosis or evidence of cirrhosis (by MELD). Not every patient had a preoperative MELD score, thus limiting our analysis of the effect of MELD on outcome. Importantly, patients who did not have preoperative bilirubin testing (or preoperative MELD) had equivalent mortality as patients with preoperative MELD, suggesting that there was no selection bias in those patients who had a preoperative MELD score. The time of this study is long, and during the study period there have been advances in anesthetic management related to patients with liver dysfunction. Because our operative database was used to identify patients, no medical control is available to identify the natural history of patients with tricuspid disease and liver dysfunction. Finally, it is difficult to separate the effect of renal failure from MELD, as MELD is directly dependent on renal function. It is possible renal dysfunction contributes significantly to the morbidity in tricuspid surgery.

At present, it is unknown if therapy aimed to lower preoperative MELD will have an impact on mortality. Early use of continuous hemofiltration or liver replacement therapy may alter the MELD score, but the effect on mortality for patients undergoing surgery is unclear. It is likely that patients with tricuspid valve dysfunction require correction of the structural problem in the way of valve surgery to treat the liver dysfunction.

In conclusion, in the present study, liver dysfunction was associated with poor outcome for patients undergoing tricuspid valve surgery. The MELD score predicts mortality among

these patients, with especially high risk for patients with a MELD score of 15 or greater. It is likely that passive hepatic congestion leading to liver dysfunction is a significant cause of mortality after tricuspid valve surgery. Compared with EuroSCORE, the MELD score offers a simple and effective method of risk stratification in patients with tricuspid disease. Further validation of MELD as a predictive tool should be performed.

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Fig 1.
Operative mortality as a function of preoperative Model for End-Stage Liver Disease (MELD) score.

Fig 2.

Comparison of the receiver operating characteristic plots for both the European System for Cardiac Operative Risk Evaluation logistic model (circles [c statistic = 0.781]) and Model for End-Stage Liver Disease model (triangles [c statistic = 0.790]) as a predictor of 30-day mortality after tricuspid valve surgery.

Table 1

Preoperative, Perioperative, and Outcome Data on Patients With History of Liver Disease or MELD Score Greater Than 15 Compared With Patients With No History of Liver Disease and MELD Score Less Than 15

Outcome	MELD 15 or Liver Disease (n = 37)	MELD 15 or No Liver Disease (n = 131)	p Value
Preoperative variables			
Age	55 [41, 63]	67 [55, 73]	< 0.0001
Male	26 (70.3%)	46 (35.1%)	0.0001
Cerebrovascular disease	6 (16.2%)	21 (16.0%)	0.99
Diabetes mellitus	8 (21.6%)	27 (20.6%)	0.89
Endocarditis	15 (40.5%)	10 (7.6%)	< 0.0001
Peripheral vascular disease	8 (21.6%)	12 (9.2%)	0.048
Renal failure	19 (51.4%)	17 (13.0%)	< 0.0001
Renal failure (hemodialysis)	9 (24.3%)	2 (1.5%)	< 0.0001
Tobacco use	22 (59.5%)	57 (43.5%)	0.086
Congestive heart failure	26 (70.3%)	91 (69.5%)	0.93
Myocardial infarction	6 (16.2%)	25 (19.1%)	0.69
Etiology of liver disease			
Alcohol-related liver disease	13 (33%)	N/A	N/A
Hepatitis B	4 (11%)	N/A	
Hepatitis C	5 (14%)	N/A	
Total bilirubin (mg/dL)	1.1 [0.8, 2.0]	1.1 [0.8, 1.4]	< 0.0001
Creatinine (mg/dL)	1.8 [1.0, 3.2]	1.0 [0.9, 3.2]	0.53
Tricuspid valve disease			
Tricuspid stenosis	1 (2.7%)	7 (5.3%)	0.69
Trace tricuspid insufficiency	0 (0.0%)	2 (1.5%)	> 0.99
Mild tricuspid insufficiency	5 (13.5%)	10 (7.6%)	0.33
Moderate tricuspid insufficiency	10 (27.0%)	28 (21.4%)	0.51
Severe tricuspid insufficiency	10 (27.0%)	49 (37.4%)	0.33
Ejection fraction (%)	55 [45, 60]	55 [40, 62.5]	0.54
Intraoperative variables			
Concomitant operations	31 (83.8%)	113 (86.3%)	0.70
Concomitant CABG	2 (5.4%)	30 (22.9%)	0.017
Concomitant mitral valve procedure	22 (59.5%)	86 (65.7%)	0.49
Concomitant AVR	12 (32.4%)	32 (24.4%)	0.33
Tricuspid valve replacement	4 (10.8%)	8 (6.1%)	0.30
Cardiopulmonary bypass time (min)	150 [123, 204]	145 [109, 184]	0.37
Postoperative outcomes			
Sepsis	5 (13.5%)	2 (1.5%)	0.0061
Stroke	1 (2.7%)	3 (2.3%)	1.0000
Myocardial infarction	1 (2.7%)	0 (0.0%)	0.22
Arrhythmia	6 (16.2%)	26 (19.9%)	0.62
Gastrointestinal complication	5 (13.5%)	4 (3.1%)	0.026

Outcome	MELD 15 or Liver Disease (n = 37)	MELD 15 or No Liver Disease (n = 131)	p Value
Multisystem organ failure	5 (13.5%)	4 (3.1%)	0.026
Pneumonia	5 (13.5%)	6 (4.6%)	0.066
Prolonged ventilation	20 (54.1%)	25 (19.1%)	< 0.0001
Renal failure	10 (27.0%)	17 (13.0%)	0.040
Renal failure (hemodialysis)	8 (21.6%)	3 (2.3%)	< 0.0001
Mortality (30 day)	7 (18.9%)	8 (6.1%)	0.024

AVR = aortic valve replacement; CABG = coronary artery bypass graft surgery; MELD = Model for End-Stage Liver Disease; N/A = not applicable.

Table 2

Preoperative, Intraoperative, and Postoperative Data for All Patients With a Calculated Model for End-Stage Liver Disease (MELD) Score

Outcome	MELD < 10 (n = 54)	MELD 10–14.9 (n = 44)	MELD 15–19.9 (n = 11)	MELD ≥ 20 (n = 13)	p Value
Preoperative variables					
Patient age	64 [49, 75]	68 [59, 73]	58 [51, 69]	56 [50, 68]	0.45
Male	23 (42.6%)	21 (47.7%)	7 (63.6%)	9 (69.2%)	0.26
Cerebrovascular disease	6 (11.1%)	8 (18.2%)	4 (36.4%)	2 (15.4%)	0.21
Diabetes mellitus	13 (24.1%)	8 (18.2%)	5 (45.5%)	3 (23.1%)	0.31
Endocarditis	5 (9.3%)	8 (18.2%)	4 (36.4%)	5 (38.5%)	0.021
Peripheral vascular disease	6 (11.1%)	2 (4.6%)	2 (18.2%)	7 (53.9%)	< 0.0005
Renal failure	3 (5.6%)	7 (15.9%)	10 (90.9%)	11 (84.6%)	< 0.0001
Renal failure (hemodialysis)	0 (0.0%)	0 (0.0%)	4 (36.4%)	6 (46.2%)	< 0.0001
Tobacco use	25 (46.3%)	22 (50.0%)	9 (81.8%)	6 (46.2%)	0.19
Congestive heart failure	39 (72.2%)	30 (68.2%)	8 (72.7%)	11 (84.6%)	0.76
Myocardial infarction	10 (18.5%)	8 (18.2%)	1 (9.1%)	4 (30.8%)	0.60
Total bilirubin (mg/dL)	1.0 [0.7, 1.3]	1.1 [1.0, 1.7]	0.9 [0.6, 1.5]	2.3 [1.3, 9.9]	0.004
Creatinine (mg/dL)	0.9 [0.8, 1.0]	1.3 [1.1, 1.5]	2.2 [1.6, 5.5]	4.3 [2.8, 6.1]	< 0.0001
Tricuspid valve disease					
Tricuspid stenosis	1 (1.9%)	4 (9.1%)	1 (9.1%)	0 (0.0%)	0.28
Trace tricuspid insufficiency	0 (0.0%)	1 (2.3%)	0 (0.0%)	0 (0.0%)	0.62
Mild tricuspid insufficiency	3 (5.6%)	3 (6.8%)	0 (0.0%)	5 (38.5%)	0.001
Moderate tricuspid insufficiency	12 (22.2%)	11 (25%)	3 (27.3%)	2 (15.4%)	0.88
Severe tricuspid insufficiency	19 (35.2%)	21 (47.7%)	3 (27.3%)	0 (0.0%)	0.02
Ejection fraction (%)	51 [39, 60]	55 [40, 60]	60 [58, 60]	50 [40, 60]	0.95
Intraoperative variables					
Concomitant operation	48 (88.9%)	35 (79.6%)	9 (81.8%)	13 (100%)	0.24
Concomitant CABG	13 (24.1%)	5 (11.4%)	1 (9.1%)	3 (23.1%)	0.36
Concomitant mitral valve procedure	38 (70.4%)	24 (54.6%)	7 (63.6%)	8 (61.6%)	0.43
Concomitant AVR	11 (20.4%)	18 (40.9%)	3 (27.3%)	5 (38.5%)	0.14
Tricuspid valve replacement	5 (9.3%)	3 (6.8%)	1 (9.1%)	0 (0.0%)	0.78
Cardiopulmonary bypass time (min)	144 [112, 181]	133 [107, 195]	140 [109, 214]	211 [157, 242]	0.027
Postoperative complications					

Outcome	MELD < 10 (n = 54)	MELD 10–14.9 (n = 44)	MELD 15–19.9 (n = 11)	MELD ≥ 20 (n = 13)	p Value
Sepsis	2 (3.7%)	2 (4.6%)	0 (0.0%)	3 (23.1%)	0.094
Stroke	1 (1.9%)	1 (2.3%)	0 (0.0%)	2 (15.4%)	0.16
Myocardial infarction	0 (0.0%)	1 (2.3%)	0 (0.0%)	0 (0.0%)	0.56
Arrhythmia	9 (16.7%)	8 (18.2%)	3 (27.3%)	3 (23.1%)	0.78
Gastrointestinal complication	1 (1.9%)	4 (9.1%)	1 (9.1%)	2 (15.4%)	0.13
Multisystem organ failure	2 (3.7%)	1 (2.3%)	2 (18.2%)	3 (23.1%)	0.019
Pneumonia	4 (7.4%)	3 (6.8%)	1 (9.1%)	2 (15.4%)	0.69
Prolonged ventilation	13 (24.1%)	12 (27.3%)	7 (63.6%)	7 (53.9%)	0.021
Renal failure	6 (11.1%)	8 (18.2%)	3 (27.3%)	5 (38.5%)	0.093
Renal failure (hemodialysis)	3 (5.6%)	3 (6.8%)	2 (18.2%)	2 (15.4%)	0.27
Mortality (30 day)	1 (1.9%)	3 (6.8%)	3 (27.3%)	4 (30.8%)	0.0015

AVR = aortic valve replacement; CABG = coronary artery bypass graft surgery.

Table 3

Univariate Analysis of Factors Related to Mortality

Outcome	Survivors (n = 153)	Died (n = 15)	p Value
Preoperative variables			
Age	64 [53, 72]	69 [58, 74]	0.23
Male	66 (43.1%)	6 (40.0%)	0.81
Cerebrovascular disease	22 (14.4%)	5 (33.3%)	0.069
Diabetes mellitus	32 (20.9%)	3 (20.0%)	1.0000
Endocarditis	23 (15.0%)	2 (13.3%)	1.0000
Peripheral vascular disease	16 (10.5%)	4 (26.7%)	0.084
Renal failure	25 (16.3%)	11 (73.3%)	< 0.0001
Renal failure (hemodialysis)	9 (5.9%)	2 (13.3%)	0.26
Tobacco use	70 (45.8%)	9 (60.0%)	0.29
Congestive heart failure	105 (68.6%)	12 (80.0%)	0.56
Myocardial infarction	26 (17.0%)	5 (33.3%)	0.16
Ejection fraction (%)	55 [40, 60]	58 [55, 60]	0.29
MELD score 15	17 (11.1%)	7 (46.7%)	0.0017
Intraoperative variables			
Concomitant operations	129 (84.3%)	15 (100%)	0.13
Concomitant CABG	30 (19.6%)	2 (13.3%)	0.74
Concomitant mitral valve procedure	99 (64.7%)	9 (60.0%)	0.72
Concomitant AVR	38 (24.8%)	6 (40.0%)	0.22
Tricuspid valve replacement	12 (7.8%)	0 (0.0%)	0.60
Cardiopulmonary bypass time (min)	145 [109, 185]	150 [129, 225]	0.12

AVR = aortic valve replacement; CABG = coronary artery bypass graft surgery; MELD = Model for End-Stage Liver Disease.