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Original Article

MELD or MELD-Na as a Predictive Model for Mortality Following Transjugular Intrahepatic Portosystemic Shunt Placement

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Abstract

Background and Aim: The model for end-stage liver disease (MELD) was originally developed to predict survival after transjugular intrahepatic portosystemic shunt (TIPS). The MELD-sodium (MELD-Na) score has replaced MELD for organ allocation for liver transplantation. However, there are limited studies to compare the MELD with MELD-Na to predict mortality after TIPS. ***Methods:*** We performed a retrospective chart review of patients who underwent TIPS placement between 2006 and 2016 at our institution. The primary outcome was mortality, and the secondary outcomes sought to assess which variables could provide prognostic information for mortality after TIPS placement. We performed receiver operating characteristic (ROC) curve analysis to assess the performance of MELD and MELD-Na. ***Results:*** There were 186 eligible patients in the analysis. The mean pre-TIPS MELD and MELD-Na were 13 and 15, respectively. Overall, mortality after TIPS was 15% at 30 days and 16.7% at 90 days. In a comparison of the areas under the ROCs for MELD and MELD-Na, MELD was superior to MELD-Na for 30-day (0.762 vs. 0.709) and 90-day (0.780 vs. 0.730) mortality after TIPS. The optimal cutoff score for 30-day mortality was 15 (0.676–0.848) for MELD and 17 (0.610–0.808) for MELD-Na, whereas the optimal cutoff score for 90-day mortality was 16 (95% CI: 0.705–0.855) for MELD and 17 (95% CI: 0.643–0.817) for MELD-Na. There were 24 patients with high MELD-Na ≥17, but with low MELD <15, and 90-day mortality in this group was 8.3%. ***Conclusions:*** Although MELD-Na is a superior prognostic tool to MELD for predicting overall mortality in cirrhotic patients, MELD tended to outperform MELD-Na to predict mortality after TIPS.

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Introduction

The transjugular intrahepatic portosystemic shunt (TIPS) is created using percutaneous endovascular techniques to treat complications of portal hypertension such as variceal hemorrhage, refractory ascites, and hepatic hydrothorax.[1–3] Careful patient selection for TIPS is vital because the resultant shunting of hepatic blood flow leads to an increased risk of post-procedure hepatic encephalopathy, liver failure, and morbidity/mortality in patients with significantly impaired liver function.[3–5] As a result, several prognostic scoring systems have been developed to assist in patient selection for TIPS placement in patients with cirrhosis.

The model for end-stage liver disease (MELD) score was first developed to predict early death of patients undergoing elective TIPS placement and was subsequently adopted for organ allocation in candidates for liver transplantation (LT) in 2002.[6,7] However, previous studies have shown that subgroups of patients are at a higher risk of mortality than predicted by their MELD score, thus restricting their access to LT.[8,9] Hyponatremia has been established as a key predictor of mortality in patients with cirrhosis independent of the MELD score. It is particularly true of patients with low MELD scores, where the effect of serum sodium is significantly greater.[8] Therefore, in January 2016, the MELD-sodium (MELD-Na) was implemented in place of the MELD for organ allocation in LT in the USA. There are limited studies comparing MELD with MELD-Na for the prediction of mortality after TIPS in patients with cirrhosis, and the existing studies have conflicting conclusions.[5,9,10] We conducted this study to investigate the prognostic ability of MELD-Na compared

Keywords: Cirrhosis; Portal hypertension; Model for end-stage liver disease; Sodium; Transjugular intrahepatic portosystemic shunt; Outcomes; Mortality.

Abbreviations: AUC, area under the ROC curve; AUROC, area under the receiver operating characteristic; CI, confidence interval; EtOH, ethyl alcohol; HCV, hepatitis C virus; ICD, international classification of diseases; INR, international normalized ratio; IQR, interquartile range; LT, liver transplantation; MELD, model for end-stage liver disease; Na, sodium; ROC, receiver operating characteristic; SD, standard deviation; TIPS, transjugular intrahepatic portosystemic shunt.

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to MELD for 30-day and 90-day mortality among patients with cirrhosis after TIPS placement.

Methods

Study design

In this observational, retrospective cohort study, adult patients (≥18 years of age) who underwent TIPS at The Johns Hopkins Hospital or Johns Hopkins Bayview Medical Center between 1 January 2006, and 31 December 2016, were retrospectively analyzed. This study was approved by the Institutional Review Board of the Johns Hopkins University School of Medicine, and informed consent was waived for a retrospective review of patient charts.

Participants and data collection

The TIPS recipients were identified using the International Classification of Diseases (ICD) code (ICD-9: 39.1, intra-abdominal venous shunt or related ICD-10 codes 06183DY and 06184DY) from Johns Hopkins electronic health records and the Johns Hopkins Interventional Radiology database for this cohort study. Two authors manually identified all TIPS recipients to confirm that the ICD-9/10 code corresponded to a new TIPS placement. Excluded were patients who underwent TIPS after LT, TIPS for noncirrhotic portal hypertension or portal vein thrombosis, and those with lack of laboratory data prior to TIPS.

Data on demographics, underlying liver disease, indication for TIPS, whether TIPS was considered urgent or elective, laboratory values, including serum sodium, serum creatinine, total serum bilirubin, and international normalized ratio (INR), and portosystemic gradients were collected before and after TIPS creation. The MELD and MELD-Na scores were calculated from laboratory data obtained within 7 days before TIPS creation in accordance with previously published formulas, with the MELD score calculated as 3.78 × ln serum bilirubin level (mg/dL) + 11.2 × ln (INR) + 9.57 × ln serum creatinine (mg/dL) + 6.43. The MELD-Na score was calculated as MELD score +1.32 × (137 − serum Na) − (0.33 × MELD score × 137 − serum Na).[6,11] Data also were collected on readmission for hepatic encephalopathy within 30 days after TIPS.

TIPS placement procedures and technique

The technique for TIPS placement was performed according to standard clinical practice by experienced interventional radiologists under general anesthesia.[12] In brief, the hepatic veins were accessed via puncture of the right internal jugular vein under direct ultrasound guidance, and venography was performed to confirm hepatic venous anatomy. The stent length was then measured using a marking catheter, and Viatorr covered stent grafts (W. L. Gore and Associates, Flagstaff, AZ, USA) were deployed across the liver tract, followed by balloon dilation. Postplacement dilation was carried out to 10 mm or 12 mm, as per the interventional radiologists' preference. Post-placement pressure measurements were then obtained. A final angiogram was performed to confirm good blood flow through the TIPS. The patients were admitted for 24 h of observation following the procedure, and subsequent outpatient care was provided in an outpatient hepatology clinic. The follow-up time was defined as the intervals from admission to death, LT, the last clinic visit, or the end of the study on 31 December 2016. All data obtained for this study were taken as part of routine care and were available in the longitudinal electronic medical records.

Study outcomes

The primary outcomes of this study were 30-day and 90-day mortality after TIPS placement. Patients were censored at last follow-up, time of transplant, or death. The secondary outcomes sought to assess which variables could provide prognostic information for mortality after TIPS placement.

Statistical analysis

Categorical variables were summarized as frequencies (*n*) and percentages (%). Chi-squared tests were used to compare categorical variables, and the Mann-Whitney-Wilcoxon test was used for continuous variables. The results are presented as median with interquartile range (IQR, 25th and 75th percentile) and means±standard deviation (SD). Univariate analysis was used to identify independent risk factors associated with the risk of death, which were then included in a multivariable model. Age, sex, ethnicity, race, body mass index, and the indications for the procedure were adjusted as confounders in the multivariable Cox proportional hazards model. Receiver operating characteristic (ROC) curve analysis was performed. The area under the curve (AUC) and 95% confidence intervals (CIs) were calculated to compare the performance of the MELD and MELD-Na in predicting mortality at 30 days and 90 days after TIPS. We identified optimal cutoff scores for both the MELD and MELD-Na using the kernel method.[13] Event-free survival rate was estimated using the Kaplan-Meier method, and the significance of differences between groups was evaluated with the log-rank test. For survival analysis, Kaplan-Meier and Cox proportional hazards regression, patients alive at the end of the study period or who were lost to follow-up were censored at the last date of clinical contact. All tests were two-tailed, and statistical significance was determined as *p*-values ≤0.05. The statistical analysis was performed using Stata software (version SE15.1; StataCorp, College Station, TX. USA).

Results

Patient characteristics

During the study period, 220 patients underwent TIPS placement. Thirty-four patients were excluded from this analysis. Seven underwent TIPS placement after LT; 26 underwent TIPS for noncirrhotic portal hypertension; and one lacked laboratory data prior to TIPS (Fig. 1), leaving a total of 186 patients eligible for analysis. Baseline demographic and clinical characteristics are summarized in Table 1. Of those patients, 108 (58.1%) were survivors, and 78 (41.9%) were nonsurvivors. The mean age was 55.7±11 years; 124 (66.7%) patients were male, and 73.1% were Caucasian. Obesity was present in 61 (31.8%) patients. The etiology of cirrhosis was 39 (21.0%), hepatitis C virus (HCV); 54 (29.0%), ethyl alcohol abuse (EtOH); 29 (15.6%), HCV/EtOH; 2 (1.1%), hepatitis B; 28 (15.1%), nonalcoholic steatohepatitis; 4 (2.2%), autoimmune hepatitis; 7 (3.8%), primary biliary cholangitis/primary sclerosing cholangitis; 1 (0.5%), hereditary hemochromatosis; and 22 (11.8%) were others. Eighty-eight (47.3%) patients had TIPS for varices, 89 (47.8%) for ascites, and 9 (4.8%) for both as-

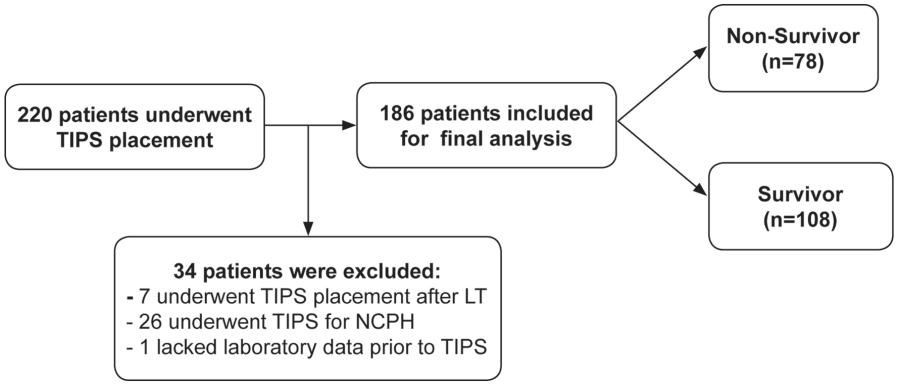

Fig. 1. Flow chart of patient selection. TIPS, transjugular intrahepatic portosystemic shunt; LT, liver transplantation; NCPH, noncirrhotic portal hypertension.

cites and varices. One hundred and thirty-six (73.1%) of TIPS were performed electively, and 50 (26.9%) were performed urgently. Laboratory values of patients before TIPS were as follows [median (IQR)]: serum bilirubin (mg/dL) 1.50 (1.0–2.5), INR 1.2 (1.1–1.5), serum creatinine (mg/dL) 1.0 (1.0–1.3), serum sodium (mEq/L) 137 (133–140). Mean pre-TIPS MELD was 13, and mean pre-TIPS MELD-Na was 15. During the mean follow-up period of 536 days, 25 (13.0%) received LT. Thirty and ninety-day mortality after TIPS was 15.0% and 16.7%, respectively.

Patient outcomes

Thirty-day mortality: Overall, 15% of patients died within 30 days of TIPS placement. The ROC AUC of MELD for predicting 30-day mortality was 0.762 (95% CI: 0.676–0.848), compared with 0.709 (95% CI: 0.610–0.808) for MELD-Na. The difference between ROC AUCs of MELD and MELD-Na was statistically significant at the borderline (p = 0.079; Table 2 and Fig. 2A). The optimal cutoff score for predicting 30-day mortality was 15 for MELD and 17 for MELD-Na.

Ninety-day mortality: Overall, 16.7% died within 90 days of TIPS placement. The ROC AUC of MELD for predicting 90-day mortality was 0.780 (95% CI: 0.705–0.855), compared with 0.730 (95% CI: 0.643–0.817) for MELD-Na. The MELD ROC AUC was not statistically superior to the MELD-Na ROC AUC (p = 0.06; Table 2 and Fig. 2B). The optimal cutoff scores for 90-day mortality for MELD and MELD-Na were 16 and 17, respectively. Twenty-four patients were deemed high risk by MELD-Na ≥17 but low risk by MELD <15.

Survival after TIPS based on MELD and MELD-Na scores: The Kaplan-Meier survival curves based on MELD and MELD-Na scores are shown in Figure 3. A log-rank test was applied to compare survival between patients with MELD scores of <10 and 10–17 and patients with MELD scores of 18–25 and >25. Overall survival following TIPS was significantly lower in patients with MELD scores of 18 or higher than those with MELD scores of 17 or lower (p<0.001 by log-rank test). Table 3 shows mortality categorized according to MELD and MELD-Na scores at 30 days and 90 days. Mortality rates were significantly increased at 30 days and 90 days in patients with MELD and MELD-Na scores of 18 or more compared with those with scores of ≤17. Furthermore, patients with MELD and MELD-Na scores >25 had a significantly higher 30-day and 90-day mortality than those with MELD or MELD-Na scores of 18–25. In addition, nonsurvivors had significantly higher pre-TIPS creatinine and total bilirubin than survivors. However, there was no difference in pre-TIPS sodium and INR between the two groups (Table 1).

Patient survival and prognostic factors for mortality

In univariate analysis, TIPS urgency, serum creatine levels, total bilirubin, and INR were associated with the highest risk of 30-day and 90-day mortality. In addition, with each one-point increase in pre-TIPS levels of serum creatinine, total bilirubin, and INR, mortality increased by 2.5-fold (95% CI: 1.55–4.30; p<0.001), 1-fold (95% CI: 1.011.29; p=0.03), and 2.5-fold (95% CI: 1.24–5.36; p=0.01), respectively (Table 4). Only TIPS urgency retained independent predictive value in multivariate analysis after adjusting for co-founders.

Discussion

In this retrospective cohort study, we analyzed a cohort of 186 patients with portal hypertension who underwent TIPS in a single center over a decade. To our knowledge, this is one of the most comprehensive studies to evaluate 30-day and 90-day mortality after TIPS placement. In addition, the patients had diverse underlying liver diseases and underwent TIPS procedures for various indications. The key findings of the study are: (1) the ROC AUC of MELD were higher than for MELD-Na for both 30-day and 90-day mortality, although the difference was not statistically significant; (2) optimal cutoff scores for MELD and MELD-Na were 15 and 17 for predicting 30-day mortality and 16 and 17 for 90-day mortality; (3) nonsurvivors had significantly higher creatinine and total bilirubin than the survivors. However, there was no difference in serum sodium between the two groups.

Our analysis showed that patients with MELD and MELD-Na scores of 18 or higher had a significantly shorter survival after TIPS than patients with MELD and MELD-Na scores ≤17. Prior studies have also compared MELD and MELD-Na in prognosticating after TIPS.[14,15] Young *et al*.[10] showed that the MELD score tended to predict mortality better than MELD-Na. A retrospective study by Gaba *et al*.[5] showed that the MELD score out performed MELD-Na (ROC AUC 0.878 vs. 0.863) in predicting mortality after TIPS at 30 days, but the MELD-Na out performed MELD at 90 days (ROC AUC 0.823 vs. 0.816). Another study by Ahmed *et al*.[16] reported results that were different from those of Gaba *et al*.[16] Ahmed *et al*.[16] performed a retrospective chart review of 69 patients who underwent TIPS placement between 2009 and 2013, and found that MELD-Na was a better predictor of mortality at both 30 days and 90 days. The authors concluded that of six predictor variables (albumin, bilirubin, creatinine, INR, MELD, and MELD-Na), only the MELD-Na

Table 1. Demographic, clinical characteristics and procedural information of the study population

Variable	Overall (*n*=186)	Nonsurvivor (*n*=78)	Survivor (*n*=108)	*p*-value
Age in years, mean±SD	55.7±11.0	56.4±11.4	55.1±10.6	0.42
Sex, *n* (%)				
Female	62 (33.3)	25 (32.1)	37 (34.3)	0.75
Male	124 (66.7)	53 (67.9)	71 (65.7)	0.75
Ethnicity, *n* (%)				
White	136 (73.1)	61 (78.2)	75 (69.4)	0.53
African American	28 (15.1)	10 (12.8)	18 (16.7)	0.53
Asian	3 (1.6)	0 (0.0)	3 (2.8)	0.53
Hispanic	4 (2.2)	2 (2.6)	2 (1.9)	0.53
Others/unknown	15 (8.1)	5 (6.4)	10 (9.3)	0.53
BMI categories, *n* (%)				
Underweight (<18.5)	2 (1.1)	0 (0)	2 (1.9)	0.83
Normal weight (8.5–24.9)	58 (31.2)	24 (30.8)	34 (31.5)	0.83
Overweight (25–29.9)	65 (34.9)	28 (35.9)	37 (34.3)	0.83
Obesity (30 or greater)	61 (32.8)	26 (33.3)	35 (32.4)	0.83
Etiology, *n* (%)				
HCV	39 (21.0)	15 (19.2)	24 (22.2)	0.18
ALD	54 (29.0)	21 (26.9)	33 (30.6)	0.18
Hepatitis C with ALD	29 (15.6)	9 (11.5)	20 (18.5)	0.18
Hepatitis B	2 (1.1)	0 (0.0)	2 (1.9)	0.18
Nonalcoholic steatohepatitis	28 (15.1)	15 (19.2)	13 (12.0)	0.18
Autoimmune hepatitis	4 (2.2)	1 (1.3)	3 (2.8)	0.18
PBC/PSC	7 (3.8)	2 (2.6)	5 (4.6)	0.18
HH	1 (0.5)	1 (1.3)	0 (0.0)	0.18
Cryptogenic/other	22 (11.8)	14 (17.9)	8 (7.4)	0.18
TIPS indication, *n* (%)				
Ascites	88 (47.3)	36 (46.2)	52 (48.1)	0.92
Varices	89 (47.8)	38 (48.7)	51 (47.2)	0.92
Ascites/varices	9 (4.8)	4 (5.1)	5 (4.6)	0.92
TIPS urgency, *n* (%)				
Elective	136 (73.1)	51 (65.4)	85 (78.7)	0.043
Urgent	50 (26.9)	27 (34.6)	23 (21.3)	0.043
Pre-TIPS Lab data, median (IQR)				
Sodium (mEq/L)	137 (133–140)	136 (132–139)	137.5 (134–140)	0.11
Creatinine (mg/dL)	1.0 (1.0–1.3)	1.2 (1.0–1.6)	1.0 (1.0–1.2)	0.002
Total bilirubin (mg/dL)	1.5 (1.0–2.5)	1.8 (1.0–3.3)	1.3 (1.0–2.3)	0.012
INR	1.2 (1.1–1.5)	1.3 (1.1–1.5)	1.2 (1.1–1.4)	0.14
Pre-TIPS, median (IQR)				
MELD	13 (10–16)	15 (11–17)	12 (9–15)	<0.001
MELD-Na	15 (12–21)	19 (15–22)	15 (11–19)	<0.001
HP (mmHg), mean±SD				
Pre-TIPS	12.39±5.78	12.97±6.22	12.03±5.49	0.32
Post-TIPS	15.92±5.90	16.71±6.37	15.38±5.53	0.18
WHVP (mmHg), mean±SD				
Pre-TIPS	30.33±7.04	30.97±8.55	29.94±5.95	0.37
Post-TIPS	22.47±6.18	22.94±6.91	22.14±5.62	0.43
HVPG (mmHg), mean±SD				
Pre-TIPS	18.34±5.76	18.36±5.95	18.33±5.66	0.98
Post-TIPS	6.80±3.11	6.50±3.14	7.01±3.08	0.28

ALD, alcoholic liver disease; BMI, body mass index; HCV, hepatitis C virus; HH, hereditary hemochromatosis; HP, hepatic pressure; HVPG, hepatic venous pressure gradient; INR, international normalized ratio; IQR, interquartile range; PBC, primary biliary cirrhosis; PSC, primary sclerosing cholangitis; SD, standard deviation; TIPS, transjugular intrahepatic portosystemic shunt; WHVP, wedged hepatic venous pressure.

Table 2. Areas under the receiver operating characteristic curve for survival at 30 days and 90 days

Value	30-day mortality		90-day mortality	
	AUROC (95% CI)	Optimal cutoff	AUROC (95% CI)	Optimal cutoff
MELD	0.762 (0.676–0.848)	15 (12.23–16.76)	0.780 (0.705–0.855)	16 (13.70–17.3)
MELD-Na	0.709 (0.610–0.808)	17 (13.75–19.25)	0.730 (0.643–0.817)	17 (14.71–18.29)
p-value	0.07		0.06	

AUROC, area under the receiver operating characteristic; MELD, model for end-stage liver disease; MELD-Na, model for end-stage liver disease sodium; CI, confidence interval.

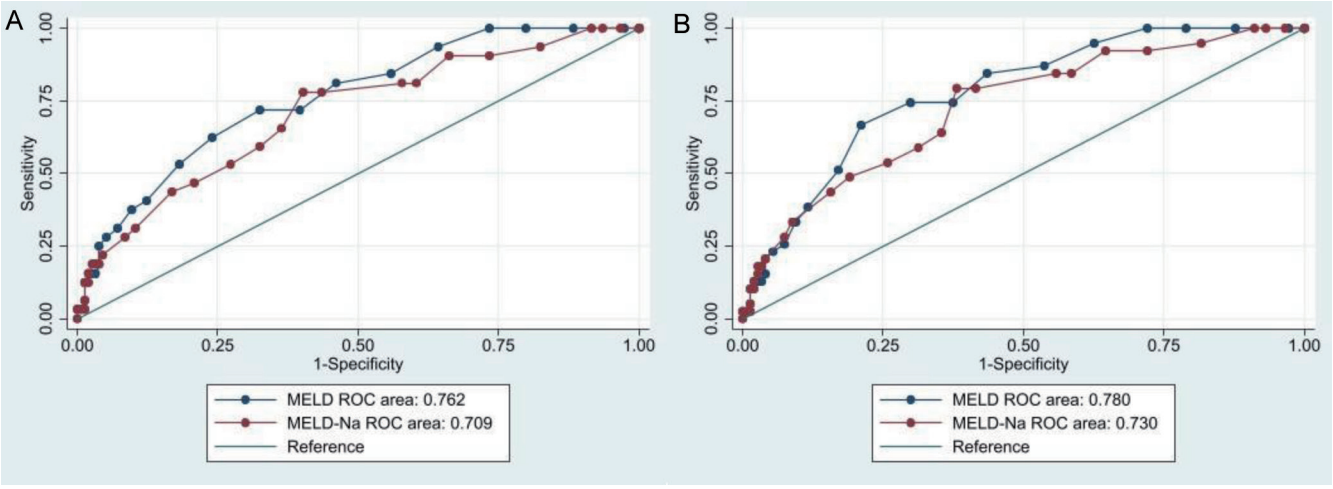

Fig. 2. AUCROC analysis of the model for MELD and MELD-Na scores. (A) ROC curves of MELD vs. MELD-Na for predicting 30-day mortality after TIPS. (B) ROC curves of MELD vs. MELD-Na for predicting 90-day mortality after TIPS. MELD, model for end-stage liver disease; MELD-Na, model for end-stage liver disease sodium; TIPS, transjugular intrahepatic portosystemic shunt.

score was a statistically significant predictor of 30-day and 90-day mortality following TIPS in patients with end-stage liver disease. However, ideal cutoff scores were not identified in that study.[16] It is important to note that the study had a small sample size.

Currently, there is no consensus concerning a safe MELD-Na score in the context of TIPS placement. In our study, we identified 24 patients with disproportionately low serum sodium and, therefore, high MELD-Na but low MELD. This subgroup of patients had a mortality of only 8.3% at 90-days. Furthermore, in our cohort, serum sodium was not an independent predictor of mortality after TIPS, perhaps because

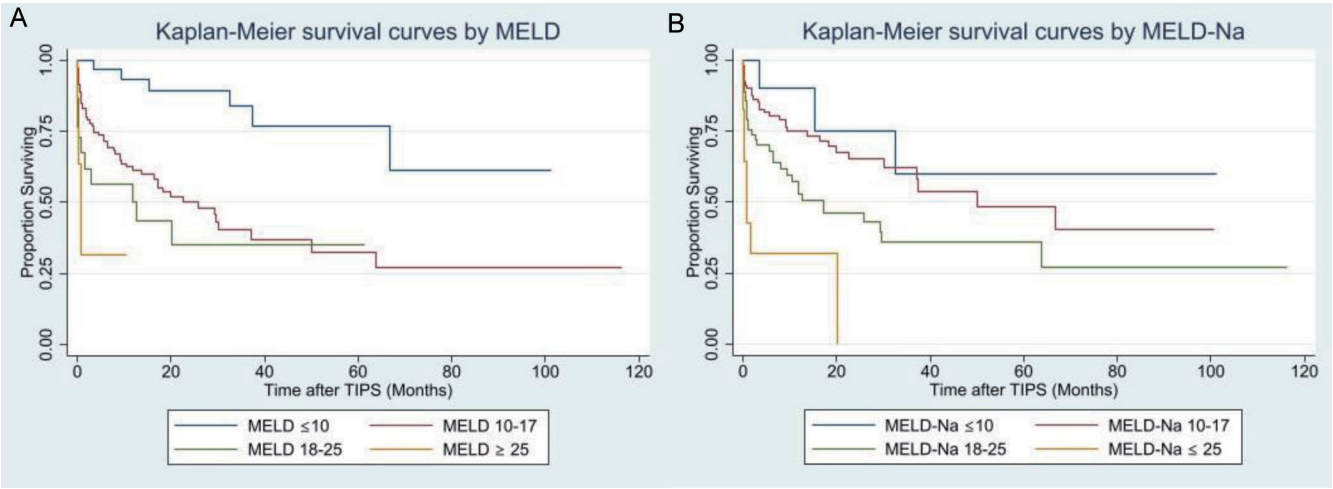

Fig. 3. Kaplan-Meier survival curves based on MELD and MELD-Na scores by predetermined categories. (A) Kaplan-Meier analysis of patient survival after TIPS creation based on MELD score scores show a significant decrease in patient survival with increasing MELD score (log-rank test, $p<0.001$). (B) Kaplan-Meier analysis of patient survival after TIPS creation based on MELD-Na score scores show a significant decrease in patient survival with increasing MELD-Na score (log-rank test, $p<0.001$). MELD, model for end-stage liver disease; MELD-Na, model for end-stage liver disease sodium; TIPS, transjugular intrahepatic portosystemic shunt.

Table 3. MELD and MELD-Na scores by predetermined categories

Scoring system and category	Score				
MELD	<10 (*n*=41)	10–17 (*n*=113)	18–25 (*n*=23)	>25 (*n*=9)	*p*-value
30-day mortality, n (%)					
Alive	41 (100)	94 (83.2)	15 (65.2)	4 (44.4)	<0.001
Dead	0 (0.0)	19 (16.8)	8 (34.8)	5 (55.6)	<0.001
90-day mortality, n (%)					
Alive	41 (100)	89 (78.8)	13 (56.5)	4 (44.4)	<0.001
Dead	0 (0.0)	24 (21.2)	10 (43.5)	5 (55.6)	<0.001
MELD-Na	<10 (*n*=13)	10–17 (*n*=96)	18–25 (*n*=65)	>25 (*n*=12)	*p*-value
30-day mortality, n (%)					
Alive	13 (100)	85 (89)	50 (77)	6 (50)	<0.001
Dead	0 (0)	11 (11)	15 (23)	6 (50)	<0.001
90-day mortality, n (%)					
Alive	13 (100)	82 (85)	47 (72)	5 (42)	<0.001
Dead	0 (0)	14 (15)	18 (28)	7 (58)	<0.001

MELD, model for end-stage liver disease; MELD-Na, model for end-stage liver disease sodium.

TIPS treats the underlying portal hypertension. Recently, Lee *et al*.[17] reported that there was no prognostic difference in outcomes of death or LT between the MELD and MELD-Na scores in a subset of patients with the highest delta MELD values at 1 year. The change in MELD was obtained by subtracting the MELD-Na score from the MELD score (ΔMELD = MELD-Na score – MELD score). Instead, Δ MELD had a protective effect on outcomes in patients classified as high risk by a MELD-Na score cutoff of 18.[17] Consistent with Lee *et al*.[17] we propose that a proportion of patients with low MELD scores but high MELD-Na scores may benefit from TIPS and should not be excluded from TIPS placement based on a high MELD-Na.

Despite analyzing a large cohort of patients, some limitations of the present study should be noted. This was a retrospective observational cohort study, which has inherent flaws. In addition, we performed an electronic health record extraction within a single health system; therefore, certain institutional practices may not be applicable in other settings. Our health system is a tertiary medical health system, possibly introducing referral bias. Also, it was not feasible to fully capture readmission data and post-procedure adverse events, as patients often present to their local hospital for initial examination without requiring transfer back to our tertiary medical health system. In addition, because many of the patients were transferred to our center from another hospital, there may have been incomplete data on pre-TIPS care, such as renal replacement therapy and the use of balloon tamponade. Despite the limitations, our study evaluated data from a large number of patients who underwent TIPS procedures performed during the course of a decade.

Table 4. Univariate and multivariate analysis of factors associated with 30-day and 90-day mortality in the entire cohort

Variable	Univariate analysis		Multivariate analysis*	
	HR (95% CI)	*p*-value	HR (95% CI)	*p*-value
Mortality 30 days				
TIPS urgency (elective vs. urgent)	5.80 (2.58–13.01)	<0.001	9.15 (1.44–58.15)	0.02
Creatinine (per mg/dL increase)	2.59 (1.55–4.30)	<0.001	1.08 (0.23–5.02)	0.92
Total bilirubin (per mg/dL increase)	1.14 (1.01–1.29)	0.03	0.87 (0.65–1.17)	0.35
INR (per unit increase)	2.58 (1.24–5.36)	0.01	0.48 (0.08–2.96)	0.43
Sodium (per mg/dL increase)	0.99 (0.92–1.08)	0.98	1.12 (0.72–1.75)	0.60
Mortality 90 days				
TIPS urgency (elective vs. urgent)	4.11 (1.95–8.65)	<0.001	8.44 (1.36–52.24)	0.02
Creatinine (per mg/dL increase)	2.81 (1.65–4.80)	<0.001	0.67 (0.15–2.91)	0.59
Total bilirubin (per mg/dL increase)	1.12 (0.99–1.27)	0.05	0.76 (0.57–1.02)	0.06
INR (per unit increase)	2.47 (1.20–5.08)	0.01	0.25 (0.04–1.47)	0.12
Sodium (per mg/dL increase)	0.97 (0.90–1.05)	0.49	1.08 (0.71–1.65)	0.72

*Age, sex, ethnicity, race, body mass index, TIPS indication, pre-TIPS lab data, pre-TIPS MELD, and MELD-Na were adjusted as confounders in the multivariable Cox proportional hazards model. TIPS, transjugular intrahepatic portosystemic shunt; INR, international normalized ratio; CI, confidence interval.

Conclusion

Although MELD-Na has largely replaced MELD in many areas related to chronic liver disease, it does not appear to be superior in predicting short-term mortality after TIPS. Importantly, there is a subgroup of patients who may be deemed high risk by MELD-Na but low risk by MELD, who have favorable outcomes after TIPS.

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Conflict of interest

The authors have no conflict of interests related to this publication.

Author contributions

Conceptualized and designed the research (MM, JPH, TW, AD), formal analysis of the data (DV, YL), interpretation of the data and writing of the original draft (AK), review and editing of the draft (AK, TAW, JPH, MM), and supervision of the project (MM, TAW). All authors revised the manuscript for important intellectual content, and approved the article's final version, including the authorship list.

Ethical statement

This study was approved by the Institutional Review Board of the Johns Hopkins University School of Medicine. Informed consent was waived for a retrospective review of patient charts. Informed consent was waived for a retrospective review of patient charts.

Data sharing statement

No additional data are available.

References

[1] Rössle M. TIPS: 25 years later. J Hepatol 2013;59(5):1081–1093. doi:10.1016/j.jhep.2013.06.014, PMID:23811307.
[2] García-Pagán JC, Caca K, Bureau C, Laleman W, Appenrodt B, Luca A, *et al*. Early use of TIPS in patients with cirrhosis and variceal bleeding. N Engl J Med 2010;362(25):2370–2379. doi:10.1056/NEJMoa0910102, PMID:20573925.
[3] Salerno F, Cammà C, Enea M, Rössle M, Wong F. Transjugular intrahepatic portosystemic shunt for refractory ascites: a meta-analysis of individual patient data. Gastroenterology 2007;133(3):825–834. doi:10.1053/j.gastro.2007.06.020, PMID:17678653.
[4] Stewart CA, Malinchoc M, Kim WR, Kamath PS. Hepatic encephalopathy as a predictor of survival in patients with end-stage liver disease. Liver Transpl 2007;13(10):1366–1371. doi:10.1002/lt.21129, PMID:17520742.
[5] Gaba RC, Couture PM, Bui JT, Knuttinen MG, Walzer NM, Kallwitz ER, *et al*. Prognostic capability of different liver disease scoring systems for prediction of early mortality after transjugular intrahepatic portosystemic shunt creation. J Vasc Interv Radiol 2013;24(3):411–420.e4. doi:10.1016/j.jvir.2012.10.026, PMID:23312989.
[6] Kamath PS, Wiesner RH, Malinchoc M, Kremers W, Therneau TM, Kosberg CL, *et al*. A model to predict survival in patients with end-stage liver disease. Hepatology 2001;33(2):464–470. doi:10.1053/jhep.2001.22172, PMID:11172350.
[7] Malinchoc M, Kamath PS, Gordon FD, Peine CJ, Rank J, ter Borg PC. A model to predict poor survival in patients undergoing transjugular intrahepatic portosystemic shunts. Hepatology 2000;31(4):864–871. doi:10.1053/he.2000.5852, PMID:10733541.
[8] Kim WR, Biggins SW, Kremers WK, Wiesner RH, Kamath PS, Benson JT, *et al*. Hyponatremia and mortality among patients on the liver-transplant waiting list. N Engl J Med 2008;359(10):1018–1026. doi:10.1056/NEJMoa0801209, PMID:18768945.
[9] Elwir S, Lake J. Current Status of Liver Allocation in the United States. Gastroenterol Hepatol (N Y) 2016;12(3):166–170. PMID:27231445.
[10] Young S, Rostambeigi N, Golzarian J, Lim N. MELD or Sodium MELD: A Comparison of the Ability of Two Scoring Systems to Predict Outcomes After Transjugular Intrahepatic Portosystemic Shunt Placement. AJR Am J Roentgenol 2020;215(1):215–222. doi:10.2214/AJR.19.21726, PMID:32432911.
[11] Leise MD, Kim WR, Kremers WK, Larson JJ, Benson JT, Therneau TM. A revised model for end-stage liver disease optimizes prediction of mortality among patients awaiting liver transplantation. Gastroenterology 2011;140(7):1952–1960. doi:10.1053/j.gastro.2011.02.017, PMID:21334338.
[12] Boyer TD, Haskal ZJ. American Association for the Study of Liver Diseases Practice Guidelines: the role of transjugular intrahepatic portosystemic shunt creation in the management of portal hypertension. J Vasc Interv Radiol 2005;16(5):615–629. doi:10.1097/01.RVI.0000157297.91510.21, PMID:15872315.
[13] Liu X. Classification accuracy and cut pointselection. Stat Med 2012;31(23):2676–2686. doi:10.1002/sim.4509, PMID:22307964.
[14] Ferral H, Vasan R, Speeg KV, Serna S, Young C, Postoak DW, *et al*. Evaluation of a model to predict poor survival in patients undergoing elective TIPS procedures. J Vasc Interv Radiol 2002;13(11):1103–1108. doi:10.1016/s1051-0443(07)61951-4, PMID:12427809.
[15] Salerno F, Merli M, Cazzaniga M, Valeriano V, Rossi P, Lovaria A, *et al*. MELD score is better than Child-Pugh score in predicting 3-month survival of patients undergoing transjugular intrahepatic portosystemic shunt. J Hepatol 2002;36(4):494–500. doi:10.1016/s0168-8278(01)00309-9, PMID:11943420.
[16] Ahmed R, Santhanam P, Rayyan Y. MELD-Na as a prognostic indicator of 30- and 90-day mortality in patients with end-stage liver disease after creation of transjugular intrahepatic portosystemic shunt. Eur J Gastroenterol Hepatol 2015;27(10):1226–1227. doi:10.1097/MEG.0000000000000412, PMID:26111072.
[17] Lee BT, Yang AH, Urban S, Kim KY, Ter-Oganesyan R, Yuan L, *et al*. Applying the original model for end-stage liver disease score rather than the model for end-stage liver disease-Na score for risk stratification prior to transjugular intrahepatic portosystemic shunt procedures. Eur J Gastroenterol Hepatol 2021;33(4):541–546. doi:10.1097/MEG.0000000000001760, PMID:32398491.