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Impact of MELD-Based Allocation on End-Stage Renal Disease After Liver Transplantation

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The proportion of patients undergoing liver transplantation (LT), with concomitant renal dysfunction, markedly increased after allocation by the model for end-stage liver disease (MELD) score was introduced. We examined the incidence of subsequent post-LT end-stage renal disease (ESRD) before and after the policy was implemented. Data on all adult deceased donor LT recipients between April 27, 1995 and December 31, 2008 (n = 59 242), from the Scientific Registry of Transplant Recipients, were linked with Centers for Medicare & Medicaid Services' ESRD data. Cox regression was used to (i) compare pre-MELD and MELD eras with respect to post-LT ESRD incidence, (ii) determine the risk factors for post-LT ESRD and (iii) quantify the association between ESRD incidence and mortality. Crude rates of post-LT ESRD were 12.8 and 14.5 per 1000 patient-years in the pre-MELD and MELD eras, respectively. Covariate-adjusted post-LT ESRD risk was higher in the MELD era (hazard ratio [HR] = 1.15; p = 0.0049). African American race, hepatitis C, pre-LT diabetes, higher creatinine, lower albumin, lower bilirubin and sodium >141 mmol/L at LT were also significant predictors of post-LT ESRD. Post-LT ESRD was associated with higher post-LT mortality (HR = 3.32; p < 0.0001). The risk of post-LT ESRD, a strong predictor of post-LT mortality, is 15% higher in the MELD era. This study identified potentially modifiable risk factors of post-LT ESRD. Early intervention and modification of these risk factors may reduce the burden of post-LT ESRD.

Key words: End-stage renal disease, liver transplant, model for end-stage renal disease, mortality, Scientific Registry of Transplant Recipients

Abbreviations: CMS, Centers for Medicare & Medicaid Services; DCD, donation after cardiac death; ESRD, end-stage renal disease; HR, hazard ratio; LT, liver transplantation; MELD, model for end-stage liver disease; RRT, renal replacement therapy; SRTR, Scientific Registry of Transplant Recipients.

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Introduction

Posttransplant chronic renal failure is a major posttransplant comorbidity among nonrenal solid organ transplant recipients and is associated with high mortality (1). Among nonrenal solid organ transplant recipients in the allocation era, before the use of the model for end-stage liver disease (MELD), liver transplant (LT) recipients had the second highest incidence of posttransplant chronic renal failure, despite lower level of immunosuppression with calcineurin inhibitors, compared to the heart and lung transplant recipients (1).

The MELD score, a measure of waiting list mortality risk, has been used as the basis of deceased-donor liver allocation since February 2002 and serum creatinine is one of the key components of the MELD score. Our previous research showed that serum creatinine is given excess weight in the current MELD formula (2). Not surprisingly, the proportion of patients undergoing LT with pretransplant renal dysfunction significantly increased in the MELD era compared to the pre-MELD era (3). Moreover, MELD is unable to distinguish between renal dysfunction due to acute and potentially reversible kidney injury, secondary to hepatorenal syndrome or due to chronic kidney disease, secondary to hypertension or diabetes.

We previously conducted a single-center MELD-era cohort study that estimated the 5-year cumulative incidence of post-LT chronic renal failure to be 22% (4). However, that study did not focus on end-stage renal disease (ESRD), and also did not have a pre-MELD comparison group. In the current study, we linked national data from the Scientific Registry of Transplant Recipients (SRTR) and the Centers for Medicare & Medicaid Services (CMS) ESRD program to determine the impact of MELD-based allocation on the incidence of new-onset ESRD among LT recipients. We also sought to determine donor and recipient risk factors associated with new-onset post-LT ESRD as well as evaluate the relationship between new-onset ESRD and post-LT mortality.

Methods

Data sources and study population

Our study was based on data obtained from the SRTR, the CMS ESRD program and the Social Security Death Master File (5). The SRTR maintains a database of all candidates for and recipients of solid organ transplants in the United States. Patients on waiting lists for organ transplantation and those who receive organ transplants are followed on a periodic basis with the use of data collection forms completed by organ-transplantation programs and submitted to the Organ Procurement and Transplantation Network. These follow-up data, in addition to data from the network regarding patients on waiting lists and the allocation of organs, are included in the SRTR database. The SRTR supplements information on vital status with data on deaths from the Social Security Death Master File and the Medicare Beneficiary Database maintained by CMS. Data collection by the SRTR is exempt from oversight under the "public benefit or service program" provisions of the Code of Federal Regulations (45 CFR 46.101[b][5]), as approved by the institutional review board of the Health Resources and Services Administration of the Department of Health and Human Services.

The Social Security Death Master File includes updated information on all participants in the Social Security system. Information on deaths reported to the Social Security system for the administration of the death, disability and retirement benefit programs is kept in the Death Master File database.

CMS maintains a database of all patients treated for ESRD in the United States, that includes information about demographics, treatment, hospitalization and costs for Medicare beneficiaries and other patients with ESRD who have received maintenance renal replacement therapy (RRT). This database also includes records of any changes in vital status or method of renal replacement, including kidney transplantation (6). Our study population included candidates 18 years of age and older who received LT between April 27, 1995 and December 31, 2008 (n = 59 242). Living donor and multiorgan transplants were excluded. The time period was divided into pre-MELD and MELD eras. Patients who received LT before February 28, 2002 were assigned to the pre-MELD era, and those who received LT on or after February 28, 2002 were assigned to the MELD era.

We constructed an analysis file containing information on the baseline demographic and clinical characteristics of the LT recipients who met inclusion criteria. The analysis file was linked to the CMS ESRD database to identify patients who received RRT after transplantation of the liver. The linkage between SRTR data and CMS data was established by matching patient-level sources, finding similarities in patient identifiers such as social security numbers, health insurance claim number, names and nicknames, gender and date of birth. More information on the nature of such linkages is described by Dickinson et al. (6).

Analytical approach

In the descriptive analysis, continuous variables were expressed as mean ± standard deviation and categorical variables were expressed as proportions. The primary outcome was new-onset post-LT ESRD, defined as the earliest of initiation of chronic dialysis, wait listing for kidney transplantation and receipt of a kidney transplant ascertained by the CMS 2728 medical evidence form. This form is completed by the patient's dialysis center within 45 days of initiation of chronic dialysis or receipt of kidney transplantation. The listing for renal transplantation was ascertained from the SRTR data. These are objective and well-defined outcomes captured in the CMS ESRD and SRTR databases. Note that the CMS 2728 form is not completed if the patient is in acute renal failure or is expected to recover renal function. Therefore, a patient who requires dialysis for some period of time, after transplantation but recovers their renal function would not be included in the CMS ESRD database. Similarly, patients who receive continuous veno-venous hemodialysis or a few courses of RRT in the immediate posttransplant phase would not be included in the CMS ESRD database. Patients in the acute phase of renal failure are not listed for kidney transplantation and, therefore, would not be in the data set either. Since, we are looking at post-LT ESRD as a primary outcome and because listing of kidney transplant is a surrogate for RRT, we included both initiation of chronic dialysis and listing for kidney transplantation as our outcome. The date of placement on the waiting list for kidney transplantation was tracked for patients with liver transplants in whom, ESRD subsequently developed. Renal replacement modality changes from dialysis to renal transplantation were also recorded in order to identify patients who received a renal transplant from either a living or deceased donor.

Patients were followed from the date of LT to the earliest of new-onset ESRD, death or the end of observation period. The incidence rate was calculated as the number of ESRD events divided by total patient time expressed as patient-years.

Given the available data structure and our objectives, death (before ESRD onset) was treated as a competing risk; i.e. since, post-LT death precludes post-LT new-onset ESRD. Therefore, we modeled the cause-specific hazard of ESRD (7), which can be thought of as the rate of ESRD incidence among patients alive and ESRD-free. An alternative approach would be to model the cumulative incidence of ESRD, which can be thought of as the follow-up time-specific probability of ESRD (acknowledging that ESRD onset cannot occur following death 0. The cumulative incidence of ESRD essentially averages over deceased and surviving patients and, hence, would be most useful for descriptive purposes.

In the first part of the analysis, Cox regression was used to contrast the pre-MELD and MELD eras with respect to ESRD incidence, adjusting for recipient's age, gender, race, diagnosis, height, weight, status, pre-LT hypertension, diabetes, hospital status at LT, previous LT, history of transjugular intrahepatic portosystemic shunt (TIPS), donor age, donor gender, cold ischemia time, local versus (regionally, nationally) shared organ and donation after cardiac death (DCD) and the type of immunosuppression. We fitted one model in contrast to covariate-adjusted ESRD incidence rates between the two eras. We, then fitted a second model that coded the year of transplant as a continuous predictor (to test for a trend over calendar time), but with a change-point at year 2002 (to test for a change in the trend beginning in 2002, the start of MELD-based allocation).

In the second part of the analysis, Cox regression was used to determine the risk factors for new-onset post-LT ESRD among LT recipients. In this case, only patients transplanted in the MELD era who were not on RRT at LT were used, because lab measurements (i.e. creatinine, bilirubin, INR, albumin) were generally not available in the pre-MELD era. The model was adjusted for all covariates listed above, plus bilirubin, international normalized ratio (INR), creatinine, change in creatinine pre-LT (slope), sodium and albumin at LT. The slope of creatinine was estimated using least squares regression, (i.e. the familiar slope estimator from simple linear regression) based on all available creatinine values from the time of wait listing to the time of LT. The MELD score update is a complex process. Serum bilirubin, creatinine and INR are components of the MELD score. For some candidates, it could be one MELD update (creatinine values) between listing and transplant while for others it could be close to 10–15 or greater MELD updates, (each including a creatinine value) available to calculate the slope.

As implied previously, we fitted proportional hazards models to the cause-specific hazard of ESRD. This was carried out using PROC PHREG in SAS v9.2 (SAS Institute, Cary, NC, USA). In particular, the input record for each patient was the covariate; time between LT and the earliest of death, ESRD,

Table 1: Cohort characteristics at the time of liver transplantation by era

Variables	Pre-MELD era (n = 25 500)	MELD era (n = 33 742)
Age at LT (years)	49.9 (10.5)	52.5 (10.2)
%Males	62%	68%
Race/ethnicity		
White	78%	73%
African American	7%	9%
Hispanic	11%	12%
Asian	4%	5%
Other	1%	1%
Hepatitis C	43%	44%
Fulminant hepatic failure	7%	7%
Donor age (years)	37.6 (17.5)	41.4 (17.5)
Cold ischemia time (hours)	8.6 (3.9)	7.5 (3.5)

loss to follow-up and end of study (with loss to follow-up and end of study, both treated as independent censoring); and an event indicator taking the value 1 for ESRD and 0 for either censoring or death. Note that the grouping of loss to follow-up, end of study and death as event = 0 should not be mistaken for an assumption that death and ESRD are independent. Coding all these events as event = 0 is merely a computational trick to make PHREG compute the risk sets appropriately. Putter et al. provide an excellent summary of related issues in the competing risks setting (8).

For the third component of the analysis, a time-dependent Cox model was used to study the association between post-LT ESRD and mortality, with ESRD (yes/no) coded as a time-dependent binary indicator.

As a subanalysis, we also modeled the rate of death before ESRD onset (i.e. cause-specific hazard of death among patients alive and ESRD-free), again using Cox regression. This model complements the first part of the analysis, in the sense that patients can cease to be alive and ESRD-free via two mutually exclusive events: ESRD onset (modeled in the first part of the analysis) and death before ESRD (the subanalysis).

All statistical analyses were conducted using SAS v9.2 (SAS Institute).

Results

Descriptive statistics

The study cohort consisted of 59 242 LT recipients (pre-MELD era: n = 25 500 and MELD era: n = 33 742). Baseline characteristics of LT recipients were similar in both eras (Table 1). On an average, LT recipients in the pre-MELD era received younger donor allografts with slightly longer cold ischemia time. Information on serum bilirubin, creatinine, INR, albumin and sodium were not available in the pre-MELD era.

Post-LT ESRD incidence rates and era effect

There were a total of 1878 and 1156 ESRD events in the pre-MELD and MELD eras, respectively. The unadjusted incidence rate of post-LT ESRD was 12.8 per 1000 patient-years in the pre-MELD era and 14.5 per 1000 patient-years in the MELD era.

LT in the MELD-based allocation era was associated with a 15% higher risk of post-LT ESRD compared to the pre-MELD era (hazard ratio [HR] = 1.15; 95% confidence interval 1.043–1.268; p = 0.0049), based on a Cox regression model adjusted for recipient's age, gender, race, diagnosis, height, weight, status, pre-LT hypertension, diabetes, hospital status at LT, previous LT, history of TIPS, donor age, donor gender, cold ischemia time, local versus (regionally, nationally) shared organ and DCD and the type of immunosuppression.

Figure 1 displays trends in covariate-adjusted post-LT ESRD incidence by calendar year of LT. Before 2002 (pre-MELD era), rates of new-onset post-LT ESRD decreased significantly by 5.1% per year (HR = 0.949; 95% confidence interval 0.924–0.975; $p < 0.0001$). However, the trend sharply reversed in 2002 (MELD era), with ESRD incidence increasing by 7.6% per year after year 2002 ($p < 0.0001$).

Subanalysis revealed that post-LT mortality (among patients alive and ESRD-free) was significantly 10% lower in the MELD era (covariate adjusted HR = 0.902; 95% confidence interval 0.864–0.941; $p < 0.0001$) relative to the pre-MELD era.

Predictors of post-LT ESRD in the MELD era

Table 2 shows recipient and donor risk factors associated with new-onset post-LT ESRD in the MELD era. African American race (HR = 1.57, $p < 0.0001$), history of diabetes (HR = 2.20, $p < 0.0001$), hepatitis C as an etiology of liver disease (HR = 1.34, $p < 0.0003$), high serum creatinine at the time of LT (HR = 4.08, $p < 0.0001$), serum sodium >141 mmol/L (HR = 1.42, $p < 0.0034$), low albumin (HR = 0.53, $p < 0.0001$), low bilirubin (HR = 0.83, $p < 0.0001$), history of TIPS (HR = 1.40 $p = 0.0013$) and history of previous LT (HR = 1.49, $p = 0.0012$) were the recipient factors associated with higher risk of new-onset post-LT ESRD. A larger increase in creatinine slope over time before LT (change in creatinine from listing to LT) was associated with a lower risk of post-LT ESRD compared to those with a smaller increase in pre-LT creatinine slope (HR = 0.86; $p < 0.0001$). INR, one of the components of MELD score, was not associated with post-LT ESRD in the MELD era (HR = 0.86; 95% confidence interval 0.691–1.072; p = 0.146).

Donor factors associated with higher risk of new-onset post-LT ESRD included age 50–69 years, male gender and DCD donor. Longer cold ischemia time was associated with higher risk of new-onset post-LT ESRD (Table 2). Neither, the type of calcineurin inhibitor nor use of antibody induction after LT affected the risk of new-onset post-LT ESRD.

Effect of post-LT ESRD on patient survival

Post-LT mortality increased more than threefold upon onset of ESRD, with covariate-adjusted HR = 3.32 ($p < 0.0001$), as shown in Table 3. Other recipient and

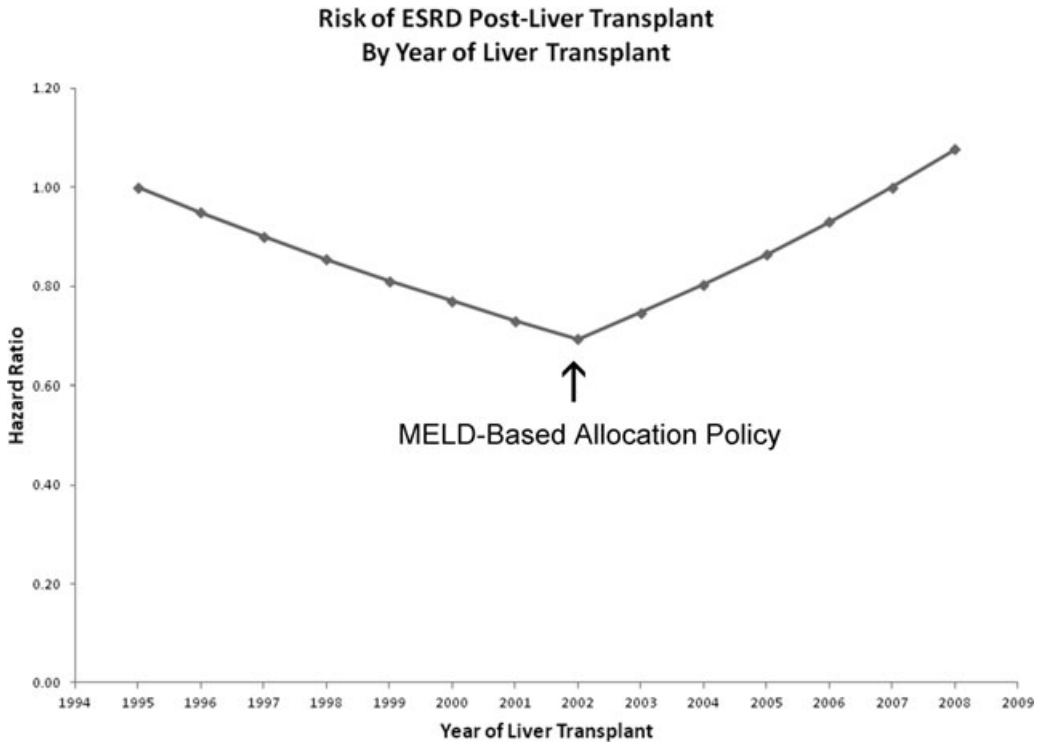

Figure 1: The risk of post-LT ESRD by the year of liver transplant. X-axis shows the year of liver transplantation and Y-axis shows the hazard ratio of post-LT ESRD. The hazard ratio for the year of liver transplantation was obtained from the regression model. Hazard ratio = $\exp^{lin\_pred}$ and lin_pred = ln(0.949) × (YEAR-1995) + ln(1.134) × (YEAR-2002) × I(Year > 2002).

donor factors predicting post-LT mortality are also listed in Table 3.

Discussion

We are not aware of any prior study that has directly evaluated the impact of MELD-based liver allocation on the risk of new-onset post-LT ESRD. Our results indicated a 15% higher risk of post-LT ESRD in the MELD era compared to the pre-MELD era, independent of the various modifiable and nonmodifiable recipient and donor risk factors that were also associated with new-onset post-LT ESRD.

Importantly, post-LT ESRD incidence rates were on the decline until MELD-based allocation took effect in 2002, after which the rates sharply reversed trend and began to increase significantly. The declining rates of ESRD in LT patients in the pre-MELD era could be a combination of centers not transplanting candidates with severe renal dysfunction (known to be associated with worse outcomes), as well as change in immunosuppression practice patterns from cyclosporine, (which is associated with slightly higher risk of post-LT chronic renal failure [HR = 1.25, $p < 0.001$]) to tacrolimus after 1994 (1,9).

Compared to the pre-MELD era, post-LT mortality was 10% lower in the MELD era among those who did not develop ESRD. This era effect reflects evolution of the field in terms of better medical and surgical patient management, better diagnostic and interventional techniques and advancement in immunosuppression (9). However, once the ESRD developed, risk of post-LT death increased threefold in our study. Although the post-LT ESRD incidence rates showed an absolute change from 12.8 per 1000 patient-years to 14.5 per 1000 patient-years in the pre-MELD era and MELD era, respectively, this 21% relative increase in post-LT ESRD incidence rates and 15% higher risk of developing post-LT ESRD in the MELD era compared to the pre-MELD era translates to a very high mortality in this group of patients.

The higher incidence of new-onset post-LT ESRD in the MELD era may represent the tip of the iceberg. We speculate that the development of post-LT Stage 4 chronic kidney disease has likely, also increased in the MELD era. This suggests that many additional cases of post-LT ESRD will be revealed over time and may add to already skyrocketing healthcare cost in terms of additional dialysis cases, and increased hospitalization rates secondary to morbidities associated with ESRD.

Table 2: Recipient and donor risk factors associated with new-onset post-LT ESRD in the MELD era

Variables	Hazard ratio (95% CI)	p-Value
Recipient factors		
Age 18–29 years (ref: 50–59 years)	0.56 (0.32–0.99)	0.046
African American (ref: white)	1.57 (1.3–1.9)	<0.0001
Cholestatic (ref: noncholestatic)	0.64 (0.47–0.88)	0.006
HCV (ref: non-HCV)	1.34 (1.15–1.58)	0.0003
Recipient diabetes	2.20 (1.92–2.52)	<0.0001
Ln Creatinine	4.08 (3.6–4.6)	<0.0001
Creatinine slope	0.86 (0.81–0.91)	<0.0001
Ln Bilirubin	0.83 (0.77–0.90)	<0.0001
Ln Albumin	0.53 (0.42–0.68)	<0.0001
Sodium >141 mmol/L/l (Ref: 130–141)	1.42 (1.12–1.79)	0.0034
TIPS recipients	1.40 (1.14–1.71)	0.0013
Previous LT	1.49 (1.17–1.89)	0.0012
Donor factors		
Donor age (ref: 30–39)		
50–59 years	1.27 (1.07–1.52)	0.0074
60–69 years	1.29 (1.05–1.60)	0.018
Donor female (ref: male)	0.86 (0.76–0.98)	0.027
Cold ischemia time (per hour)	1.03 (1.01–1.04)	0.0004
DCD (ref: non-DCD)	1.47 (1.10–1.97)	0.0098

HCV = hepatitis C; LT = liver transplant; DCD = donation after cardiac death.

Pre-LT serum creatinine was one of the strongest predictors of post-LT ESRD in our study. Because creatinine is heavily weighted in the MELD equation currently used for allocation (2), the MELD era has been characterized by a significantly higher proportion of candidates undergoing LT with serum creatinine ≥2 mg/dL compared to the pre-MELD era (3). This has increased the number of recipients at high risk for new-onset post-LT ESRD.

Interestingly, a steeper slope of creatinine during the interval from the time of listing to LT was associated with a lower risk of post-LT ESRD. A plausible explanation for this observation is that a rapid rise in creatinine before LT may represent an acute renal injury secondary to hepatorenal syndrome, which would be expected to improve after successful LT. Conversely, candidates with a more gradual rise in creatinine are more likely to have preexisting structural renal disease, which may progress to post-LT ESRD over time.

In addition to previously identified risk factors for new-onset post-LT ESRD such as African American race, history of pre-LT diabetes and high pre-LT creatinine (1,10–13), our study also showed that serum sodium >141 mmol/L, lower albumin, lower bilirubin, history of TIPS and previous LT were each significantly and independently associated with new-onset post-LT ESRD. Lower albumin levels and history of TIPS represent an advanced stage of cirrhosis. High serum sodium may represent a volume-depleted state, whereas low serum sodium is often associated with potentially reversible hepatorenal syndrome.

Our analysis did not identify gender as a predictor of ESRD risk following LT. The degree to which creatinine understates ESRD risk among females may not have been of sufficient magnitude to produce an independently significant gender effect. Also, the degree to which creatinine understates ESRD risk may be lower in post-LT patients.

Our study also showed that a diagnosis of hepatitis C and noncholestatic liver disease were associated with a higher risk of post-LT ESRD compared to nonhepatitis C and cholestatic liver disease, respectively. Hepatitis C is a frequent diagnosis among noncholestatic liver disease patients and a lower bilirubin level is commonly seen in noncholestatic liver disease. The number of candidates listed and transplanted for hepatitis C has increased over time (14,15). Candidates with hepatitis C may have preexisting intrinsic kidney disease, secondary to membranous or membrano-proliferative glomerulonephritis, which may eventually progress to post-LT ESRD.

Various donor factors such as advanced age (≥50 years), male gender, prolonged cold ischemia time and DCD donor type were associated with a higher risk of post-LT ESRD. These donor factors have also been shown to be associated with poor graft survival (16).

The primary limitation of our study is the retrospective observational study design that may result in the potential for bias due to patient selection and unmeasured patient characteristics. Moreover, this study was unable to evaluate the causes of post-LT ESRD because of the lack of renal biopsy and urinalysis information in SRTR data. An additional limitation is unavailable or missing data on creatinine, bilirubin and INR from the pre-MELD era, which could have been used to determine whether the adverse effects of these covariates on post-LT ESRD varied by allocation era. Despite these limitations, this is the largest cohort study from the MELD era to evaluate the impact of current liver allocation policy on post-LT ESRD. The primary outcome of our study was new-onset post-LT ESRD, as opposed to chronic renal failure which was used in previous studies (1,4). Post-LT ESRD is more reliably tracked and ascertained than Stage 4 chronic kidney disease.

In conclusion, our study has demonstrated that the risk of new-onset ESRD among LT recipients is markedly higher in the MELD era. The risk of post-LT ESRD, which had been declining before the implementation of MELD-based allocation, has increased by 7.6% per year, since its introduction in 2002. Because the development of ESRD is associated with very high mortality among LT recipients, risk modification directed toward optimizing renal function may be useful in the pre, peri and postoperative management of LT candidates and may prevent or delay post-LT ESRD. These measures may have a significant downstream effect on decrease in the need for dialysis, post-LT ESRD related mortality, need for renal transplantation and healthcare cost. Finally, reweighting of creatinine

Table 3: Predictors of post-LT mortality

Variables	Hazard ratio	95% CI	p-Value
Post-LT ESRD (time dependent)	3.32	2.96–3.71	<0.0001
Age 18–29 years (ref: age 50–59 years)	0.85	0.72–1.00	0.0429
30–39	0.80	0.71–0.91	0.0009
40–49	0.88	0.82–0.94	0.0001
60–64	1.18	1.09–1.27	<0.0001
65 and above	1.40	1.29–1.52	<0.0001
African American (ref: white)	1.25	1.15–1.36	<0.0001
Hispanic	0.86	0.79–0.93	0.0003
Asian	0.80	0.70–0.92	0.0012
Hepatitis C (ref: non-HCV)	1.39	1.31–1.48	<0.0001
HCC (ref: non-HCC)	1.34	1.25–1.44	<0.0001
Pre-LT DM (ref: no DM)	1.18	1.11–1.25	<0.0001
Ln Creatinine at LT	1.13	1.07–1.20	<0.0001
Ln Albumin at LT	0.73	0.66–0.81	<0.0001
Hospitalized ICU (ref: ambulatory)	1.34	1.20–1.50	<.0001
Hospitalized non ICU	1.16	1.07–1.25	0.0001
Mechanical life support at LT (ref: no mechanical life support)	1.58	1.40–1.79	<0.0001
Status 1 (ref: non-status 1)	0.74	0.64–0.85	<0.0001
Repeat LT (ref: no)	1.70	1.54–1.87	<0.0001
Portal vein thrombosis (ref: none)	1.39	1.25–1.56	<0.0001
Donor age 0–17 (ref: 18–39)	0.90	0.81–1.003	0.0571
40–49	1.20	1.12–1.29	<0.0001
50–59	1.32	1.23–1.42	<0.0001
60–69	1.58	1.46–1.72	<0.0001
70 and above	1.71	1.53–1.90	<0.0001
Cold ischemia time	1.01	1.004–1.02	0.0030
DCD (ref: no)	1.25	1.10–1.43	0.0006
Regional (ref: local)	1.03	0.97–1.10	0.2893
National	1.16	1.05–1.28	0.0034

in the MELD formula should be considered (2). This modest modification to the allocation system may balance the desire to improve overall post-LT outcomes while reducing the risk of renal failure and reducing wait-list mortality.

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Disclosure

The authors of this manuscript have no conflicts of interest to disclose as described by the *American Journal of Transplantation*.

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