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A comparison of liver transplantation outcomes in the pre- vs. post-MELD eras

F. KANWAL*,†,§,¶, G. S. DULAI*,†,‡,§,¶, B. M. R. SPIEGEL*,†,‡,§,¶,**, H. F. YEE*,†,‡,¶ & I. M. GRALNEK*,†,‡,§,¶,**

*VA Greater Los Angeles Health Care System, Divisions of Gastroenterology/Hepatology and General Internal Medicine/Health Services Research, Los Angeles, CA, USA; †David Geffen School of Medicine at UCLA; ‡CURE Digestive Diseases Research; §Center for the Study of Digestive Healthcare Quality and Outcomes; ¶UCLA Center for the Health Sciences; **UCLA Center for Neurovisceral Sciences and Women's Health, Los Angeles, CA, USA

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SUMMARY

Background: The model for end stage liver disease (MELD)-based organ allocation system is designed to prioritize orthotopic liver transplantation (OLT) for patients with the most severe liver disease. However, there are no published data to confirm whether this goal has been achieved or whether the policy has affected long-term post-OLT survival.

Aim: To compare pre-OLT liver disease severity and long-term (1 year) post-OLT survival between the pre- and post-MELD eras.

Methods: Using the United Network of Organ Sharing database, we compared two cohorts of adult patients undergoing cadaveric liver transplant in the pre-MELD ($n = 3857$) and post-MELD ($n = 4245$) eras. We created multivariable models to determine differences in: (i) pre-OLT liver disease severity as measured by MELD; and (ii) 1-year post-OLT outcomes.

Results: Patients undergoing OLT in the post-MELD era had more severe liver disease at the time of transplantation (mean MELD = 20.5) vs. those in the pre-MELD era (mean MELD = 17.0). There were no differences in the unadjusted patient or graft survival at 1 year post-OLT. This difference remained insignificant after adjusting for a range of prespecified recipient, donor, and transplant centre-related factors in multivariable survival analysis.

Conclusions: Although liver disease severity is higher in the post- vs. pre-MELD era, there has been no change in long-term post-OLT patient or graft survival. These results indicate that the MELD era has achieved its primary goals by allocating cadaveric livers to the sickest patients without compromising post-OLT survival.

INTRODUCTION

Although the model for end stage liver disease (MELD)-based organ allocation system is designed to prioritize orthotopic liver transplantation (OLT) for patients with the most severe liver disease, there are no published data to confirm that this goal has been achieved. Specifically, there has been no previous attempt to measure whether liver disease severity at the time of OLT is higher in the post- vs. pre-MELD era. Nonetheless, assuming that the MELD era has indeed allowed sicker patients to be transplanted sooner,[1,2] a plausible assumption would be that post-OLT outcomes are now worse compared with the pre-MELD era. However, recent data do not bear this out as they demonstrate unchanged 3-month patient and graft survival in the post- vs. pre-MELD eras.[1] Given that pre-OLT liver disease severity is the most important determinant of

Correspondence to: Dr I. M. Gralnek, VA Greater Los Angeles Healthcare System, David Geffen School of Medicine, UCLA, 11301 Wilshire Blvd., Bldg. 115, Room 215, Los Angeles, CA 90073, USA.
E-mail: igralnek@mednet.ucla.edu

post-OLT outcomes,[3, 4] there appears to be a disconnect between the purported increase in pre-OLT severity and the lack of change in post-OLT outcomes. The source of this apparent disconnect is unclear. Potential explanations might include: (i) pre-OLT liver disease severity is not a predictor of post-OLT outcomes; (ii) transplant recipients are, in fact, not sicker in the post- vs. pre-MELD eras; (iii) post-OLT outcomes have indeed worsened but have not yet been detected as reported outcomes have been limited to only 3-month post-OLT.

The first explanation is unlikely given the extensive validation to the contrary.[3, 4] The remaining two explanations are plausible and have not been systematically appraised. The MELD based system prioritizes patients with more severe liver disease. The MELD system also prioritizes patients with renal insufficiency, and patients with hepatocellular carcinoma. All these factors are associated with decreased patient and graft survival.[3–6] In light of these, our aim was to reassess the contention that sicker patients are receiving cadaveric livers and that the post-OLT outcomes are stable in the post-MELD era. We therefore sought to test the hypotheses that: (i) pre-OLT liver severity is higher; and (ii) post-OLT patient and graft survival are lower in the post- vs. pre-MELD era. To test our first hypothesis, we performed a multivariable analyses in over 8000 orthotopic liver transplant recipients using the United Network of Organ Sharing (UNOS) liver transplant database to determine whether the mean pre-OLT liver disease severity increased in the post-MELD era compared with the pre-MELD eras. To test our second hypothesis, we conducted a multivariable survival analysis to determine whether 1-year patient and graft survival worsened in the post-MELD era compared with the pre-MELD eras.

MATERIALS AND METHODS

Subjects

We identified two cohorts of OLT recipients using the UNOS Standard Transplant Analysis and Research liver transplant database: (i) Pre-MELD cohort – those undergoing OLT from 1 January 2001 to 31 December 2001 ($n = 3857$); and (ii) Post-MELD cohort – those undergoing OLT between 1 March 2002 and 28 February 2003 ($n = 4245$). We limited our study to consecutive adults patients (≥ 18 years) who received a cadaveric OLT. We excluded patients undergoing OLT for fulminant hepatic failure and patients undergoing living related liver transplantation because the MELD based prioritization for organ transplantation is not applicable to these subsets of recipients.

Study outcome measures

In order to test our study hypotheses, we evaluated two separate study outcomes: pretransplant liver disease severity and post-transplant patient and graft survival.

Pretransplant liver disease severity. Pre-OLT liver disease severity has traditionally been assessed with a variety of measures, including direct clinical indicators such as complications of portal hypertension[7–9] and UNOS status,[4] and indirect indicators such as need for intensive care unit care and 'called from home vs. in-hospital' at the time of OLT.[4] Any observed differences in these direct and indirect measures may be a direct consequences of the MELD-based policy change and therefore may not be reliable as indicators of change in liver disease severity. In contrast, MELD score has been proposed as a valid and reliable measure of liver disease severity[10, 11] and we therefore selected this variable as our primary measure of pre-OLT liver disease severity.

The UNOS began collecting MELD score data in November 2001. Data regarding pretransplant MELD score (reported MELD) were therefore present in majority of patients included in the post-MELD cohort. Conversely, only a small proportion of pre-MELD patients had reported MELD data. We calculated a laboratory MELD score for all OLT recipients in the pre- and post-MELD cohorts from the serum bilirubin, International normalized ratio (INR) of the prothrombin time, and serum creatinine at the time of OLT as reported elsewhere ('calculated MELD').[11] As recommended by UNOS, serum creatinine was set at 4 mg/dL in the MELD equation for patients receiving pre-OLT dialysis.[12]

In order to determine whether the 'reported' and 'calculated' MELD scores were similar, we performed a preliminary correlation analysis between these two scores among OLT recipients in which both methods of measuring MELD were possible ($n = 2450$). This analysis demonstrated a high correlation between the reported and calculated MELD ($r = 0.80$). Further descriptive analysis showed that the mean ± s.d. difference between reported and calculated MELD was

2.5 ± 6.0, and that these differences were normally distributed – thereby demonstrating lack of systematic error (i.e. over or under-estimation) in the calculation of MELD scores. Given the complete nature of reported MELD data in the post-MELD cohort, and given a high correlation between reported and calculated MELD scores, we used reported MELD scores as the liver disease severity measure in the post-MELD cohort and calculated MELD scores as the liver disease severity measure in the pre-MELD cohort. As recipients with hepatocellular cancer (HCC) received a high 'exception' MELD score under the MELD-based policy change, the reported MELD scores for HCC patients do not reflect the severity of underlying synthetic function. As a result, we used calculated MELD scores as liver disease severity index in HCC patients. Although these empirical data indicate that the calculated MELD scores are a strong surrogate for the reported MELD scores and therefore may be used interchangeably, a potential of measurement bias persists. Therefore, we conducted sensitivity analyses using the calculated MELD scores as liver disease severity index in all patients.

Patient and graft survival. One-year survival is a reliable surrogate for long-term (5-year) survival in liver transplantation and therefore is a clinically relevant outcome in liver transplant recipients.[13, 14] In order to obtain complete ascertainment of mortality in the study subjects, we linked the UNOS database with the Social Security Master Death File (SSMDF). This approach is known to yield nearly complete death ascertainment for anyone receiving a transplant.[15] We assumed that the patient was alive at the end of the study (1-year post-OLT) if no death was reported from both sources (UNOS and SSDMF) during that time frame. Follow-up was terminated at either the time of the patient's death, or at the end of the study period for patient survival. The follow-up was terminated at the time of re-transplantation, time of patient's death, time of last follow-up visit, or at the end of the study period for graft survival.

Conceptual model

Pretransplantation liver disease severity. Several factors may confound the direct estimate of the difference in the pre-OLT liver disease severity between the post- vs. pre-MELD era. These include well known differences in liver organ availability and HCC-related OLT rates between the cohorts.[1] For example, the cadaveric liver organ availability increased significantly in the post- vs. the pre-MELD era.[1] Greater organ availability is likely to result in more OLT procedures at any given time. This increase in the rate of OLT may have 'diluted' the mean liver disease severity in the post- vs. the pre-MELD cohorts by expanding the pool of OLT recipients. Furthermore, recipients with HCC have less severe pre-OLT liver disease vs. recipients with non-HCC related indications. Given a significant increase in the rates of OLT for HCC in the post- vs. pre-MELD cohorts, failure to account for HCC may falsely diminish the difference in disease severity between the post- and pre-MELD cohorts. Based upon these hypothesized associations and directional effects, we controlled for organ availability at the time of OLT (operationalized as the number of OLTs performed in the month the recipient underwent OLT) and HCC status while estimating the difference in liver disease severity among the two cohorts.

Patient and graft survival. As patient and graft survival depend upon several recipient,[5, 6, 16–20] donor,[21–25] and transplant centre related factors,[26] we developed a conceptual model to specify the relevant variables that might affect the post-OLT outcomes among our study cohort. We based our conceptual model upon *a priori* hypotheses guided by empirical data from the literature.[5, 6, 16–26] Table 1 provides the full list of covariates and their method of categorization. We excluded variables from the primary analysis if they were deemed to be: (i) a direct consequence of the MELD-based policy change; and (ii) a direct cause of possible change in the outcome. For example, the negative impact of the post-MELD era on survival may be the result of an increase in the pre-OLT liver disease severity in the post-MELD cohort. Adjusting for liver disease severity will mask the difference in the post- vs. pre-MELD era. Therefore, we excluded pre-OLT liver disease severity from our primary survival analysis. Similarly, we excluded HCC status (whether or not patient received OLT for HCC) and combined kidney–liver transplantation from the primary analyses. However, we then performed several exploratory analyses to examine the effect of these excluded variables on the model results, as discussed below.

Statistical analysis

We analysed patient data using Stata Statistical Software Release 8.0 (Stata Corporation, College Station,

Table 1. Descriptive statistics for measured variables specified in the conceptual model in the study cohort

Variables	pre-MELD ($n = 3857$)	post-MELD ($n = 4245$)	P-value
Recipient variables			
Socio-demographics			
Age, mean (s.d.)	51 (9.3)	51 (9.6)	0.4
Gender, male (%)	70.9	69.9	0.4
Race, (%)			
White	85.6	84.8	0.7
African American	6.7	8.2	0.03
Asian	4.1	4.3	0.6
Other	3.5	2.5	0.03
Diagnosis (%)			
Chronic hepatitis C	33	34	0.5
Chronic hepatitis B	5.3	4.5	0.1
Alcohol	23.9	18.7	<0.0001
Hepatocellular cancer*	3.1	22.2	<0.0001
Other diagnoses	34.7	33.8	0.7
Other recipient characteristics (%)			
≥1 medical comorbidity	32	33	0.07
Previous transplantation	7.9	6.3	0.02
Combined kidney–liver transplantation	2.4	4.3	<0.0001
Donor variables			
Transplants/month, mean (s.d.)	324 (28)	356 (27)	<0.0001
Donor age, mean (s.d.)	38.9 (17)	39.4 (17)	0.13
Gender mismatch (%)	40	39	0.3
Cold ischaemia, mean (s.d.)	7.8 (3)	7.7 (3)	0.1
Warm ischaemia, mean (s.d.)	39.6 (18)	40.6 (19)	0.08
Non-heart beating donor (%)	1.8	1.8	0.8
Whole liver (%)	98.3	98.1	0.4
Transplant centre variables			
Proportion of transplants per centre volume, (%)			0.5
Low (<20 transplants/year)	57.1	58.3	
Medium (20–50 transplants/year)	38.6	37.6	
High (>50 transplants/year)	4.3	4.1	
Outcome variables			
MELD Score, mean (s.d.)	17.0 (9.7)	20.5 (9.6)	<0.0001
Proportion of recipients dead at year-1 (%)	11.2	11.1	0.82
Time to death, mean (s.d.)	105.4 (108)	113.6 (107)	0.2
Proportion of grafts failed year-1 (%)	18.7	17.4	0.11
Time to graft failure, mean (s.d.)	90.9 (102)	99.2 (104)	0.13

s.d., standard deviation; MELD, model for end stage liver disease.
* A large fraction of hepatocellular carcinoma patients also had other underlying liver disease, especially chronic hepatitis C. As a result, the percentages in the diagnosis categories do not add up to 100%

TX, USA). All P-values were two-sided using an alpha of 0.05 as the standard for determining significance. For descriptive analyses, we summarized the continuous variables using means or medians and categorical variables as proportions. We conducted between group comparisons using t-tests or Kruskal–Wallis tests for continuous variables and χ^2 tests for categorical variables.

Pretransplantation liver disease severity. We conducted a multivariable linear regression analysis to estimate the difference in pre-OLT liver disease severity between the post- vs. pre-MELD cohorts while adjusting for potential confounders (as discussed in Conceptual model, above). Diagnostic statistics revealed no deviation from the normality or equal variance assumptions, no evidence of severe outliers, and no evidence of severe multicollinearity.

B) Patient and graft survival. We calculated survival curves using the Kaplan–Meier method and compared survival function using log-rank statistics. We then conducted a Cox proportional-hazards model to control for potential confounders. We included all *a priori* selected covariates in the final models rather than performing a potentially arbitrary stepwise regression analysis. We tested the proportional-hazards assumption in all models and the assumption appeared valid. We used the likelihood ratio test in the Cox models to evaluate the significance of the observed differences in the post-MELD vs. pre-MELD eras.

RESULTS

Sample characteristics

Table 1 lists the descriptive results for all the sample characteristics. The mean age ± s.d. at OLT was 51 ± 9 years in both the pre- and post-MELD cohorts. Seventy per cent of the patients were men and 85% were white in both cohorts. African Americans were more likely to receive an OLT in the post-MELD compared with the pre-MELD cohort. There was a sevenfold increase in the proportion of recipients receiving OLT for HCC and a 22% decrease in the proportion receiving OLT for alcohol related liver disease in the post- vs. pre-MELD cohort. Furthermore, the proportion of OLT recipients undergoing combined kidney–liver transplantation increased and the proportion undergoing second or third liver transplantation decreased in the post- vs. pre-MELD cohort.

There was a significant increase in the monthly rate of OLTs in the post- vs. pre-MELD era (324 ± 28/month vs. 356 ± 27/month; $P < 0.0001$). There were no differences in donor age, proportion with gender mismatch, cold or warm ischaemia times, proportion of organs from non-heart beating donors, and type of OLT between the two cohorts. Similarly, there were no differences in the proportion of OLTs performed in the low, medium, and high volume centres in the post- vs. pre-MELD cohorts.

Pretransplantation liver disease severity

The MELD scores were available for 88% of the post-MELD cohort and 51% of the pre-MELD cohort. The mean MELD score was significantly higher in the post-MELD (20.5 ± 9) vs. the pre-MELD (17.0 ± 9) cohort ($P < 0.0001$) (Table 1). As shown in Table 2, this difference was accentuated after adjustment for organ availability and OLT for HCC. The multivariable regression analysis stratified by HCC revealed that the higher liver disease severity in the post-MELD cohort was attributable entirely to the higher liver disease severity among patients undergoing OLT for non-HCC related indications (Table 2). Specifically, the mean MELD score for non-HCC patients in the post-MELD cohort was 5 points higher than the non-HCC patients in the pre-MELD cohort (95% CI = 4.6, 5.6; $P < 0.0001$). Conversely, there was no difference in the mean MELD scores for the HCC patients between eras. The analysis using calculated MELD score in all patients did not change the results (data not shown).

Post-transplantation patient and graft survival

Figure 1 displays the Kaplan–Meier survival graphs for the post- vs. the pre-MELD cohorts. There was no difference in the unadjusted post-OLT 1-year patient or graft survival between the cohorts. These results did not change after adjusting for prespecified covariates. Although there was a 3% decrease in 1-year mortality in the post- vs. pre-MELD era (hazard ratio = 0.97), this difference was not statistically significant (95% CI =

Table 2. Difference in pretransplantation liver disease severity between the post-MELD vs. Pre-MELD cohorts

	Difference in MELD score (95% CI) post- vs. pre-MELD	*P*-value
All patients – unadjusted	3.5 (3.0, 4.0)	<0.0001
All patients – adjusted*	4.7 (4.2, 5.3)	<0.0001
Patients without hepatocellular cancer†	5.1 (4.6, 5.6)	<0.0001
Patients with hepatocellular cancer†	−0.05 (−1.5, 1.4)	0.9

CI, confidence interval; MELD, model for end stage liver disease.
* Adjusted for hepatocellular carcinoma status and number of transplants performed in the month the recipient underwent orthotopic liver transplantation (OLT) (surrogate for organ availability).
† Adjusted for number of transplants performed in the month the recipient underwent OLT.

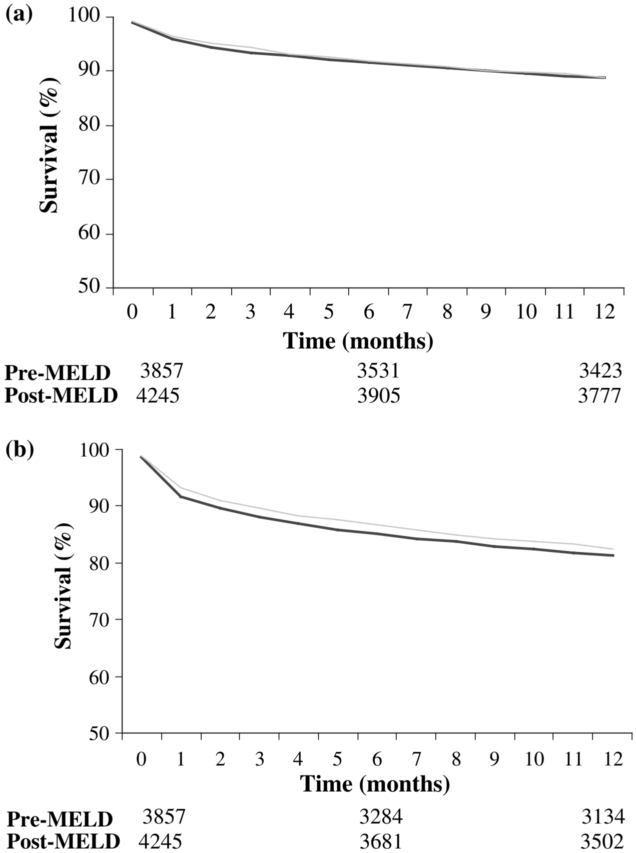

Figure 1. Post-liver transplantation outcomes post-MELD vs. pre-MELD. There is no difference in patient survival (a) and graft survival (b) at 1 year between the post- and pre-MELD cohorts.

0.8, 1.2; $P = 0.7$). Similarly, there was no statistically significant difference in graft survival in the post- vs. pre-MELD cohort (hazard ratio = 0.92; 95% CI = 0.9, 1.1; $P = 0.3$).

We conducted two exploratory analyses to help elucidate the apparent disconnect between the increase in mean liver disease severity at the time of OLT and the lack of change in post-OLT outcomes between the eras. First, as the post-OLT outcomes are different between patients undergoing OLT for HCC vs. non-HCC disease,[4] we performed separate multivariable survival analyses in patients with and without HCC. As shown in Table 3, there were no differences in patient or graft survival between the eras regardless of the HCC status. Secondly, we forced MELD scores into the survival model as a separate independent variable to test whether pre-OLT MELD score itself predicts post-OLT survival. This analysis is useful because if MELD scores do not predict post-OLT survival, then this would explain why post-

Table 3. Results of multivariable patient and graft survival analysis

Post-MELD vs. pre-MELD era	Hazard ratio	Standard error	95% CI	*P*-value
Patient mortality				
All patients	0.97	0.07	0.8, 1.2	0.7
Patients without hepatocellular cancer	1.00	0.10	0.8, 1.2	0.6
Patients with hepatocellular cancer	0.84	0.27	0.4, 1.6	0.9
Graft failure				
All patients	0.92	0.07	0.9, 1.1	0.6
Patients without hepatocellular cancer	0.96	0.07	0.8, 1.1	0.3
Patients with hepatocellular cancer	0.88	0.22	0.5, 1.4	0.6

All analyses are adjusted for recipient variables including age at transplant, gender, race, diagnoses, non-liver related comorbidity, and previous transplantation; donor variables including organ availability, age of donor at death, gender mismatch, cold and warm ischaemia time, non-heart beating donor, and whole vs. partial liver transplant; and transplant centre volume. We did not adjust for pretransplantation MELD score, hepatocellular cancer, and combined kidney–liver transplantation in the primary analyses.
CI, confidence interval; MELD, model for end stage liver disease.

OLT survival has not decreased despite an increase in pre-OLT MELD scores. However, our analysis revealed that MELD was indeed highly predictive (hazard ratio = 1.033; 95% CI = 1.02, 1.04; $P < 0.0001$) of 1-year post-OLT patient survival. For example, a 10-point increase in pre-OLT MELD was associated with a 39% increase in patient mortality within the first year. Similarly pre-OLT MELD score independently predicted 1-year graft survival (hazard ratio = 1.02; 95% CI = 1.01, 1.03; $P < 0.0001$).

DISCUSSION

Our analysis of the UNOS liver transplant database reveals that the most important post-transplantation outcomes – namely patient and graft survival – have not been compromised since the implementation of the MELD-based liver allocation system in February 2002. Our analysis further demonstrates that the unchanged survival is not because of the higher proportion of recipients with HCC in the post- vs. pre-MELD cohort – patients who might otherwise have a better underlying synthetic liver function and therefore a better 1-year survival compared with patients without HCC requiring OLT. In fact, patient and graft survival were stable both in patients with and without HCC. Our results provide convergent validity to the recent report by Freeman *et al.* that short-term (3-month) post-OLT survival has remained stable in the pre- vs. post-MELD eras.[1] Our data extend this observation by demonstrating stable survival over 1 year. This is the first report of extended survival outcomes in liver transplant recipients since the implementation of the MELD-based organ allocation system. In light of the positive association between 1- and 5-year survival described in previous work,[13, 14] our results suggest that the 5-year outcomes may also remain unchanged in the post- vs. pre-MELD cohorts.

Our data indicate that there is a disconnect between pre-OLT liver disease severity and post-OLT outcomes. Specifically, despite the plausibility that higher pre-OLT severity would lead to lower post-OLT survival, our data fail to confirm this hypothesis. One explanation for the disconnect is that pre-OLT severity is not a predictor of post-OLT survival. However, our data indicate the pre-OLT MELD scores are highly predictive of survival, as might be expected. Therefore, this first explanation is not tenable. A second possible explanation is that transplant recipients are simply not sicker in the post- vs. pre-MELD eras. However, our data indicate that pre-OLT severity has in fact increased with the adoption of the MELD-based allocation system – an expected outcome as the system was explicitly designed to prioritize the sickest patients. Therefore, this second explanation cannot account for the observed disconnect. A third potential explanation is that post-OLT outcomes have indeed worsened but have not yet been detected. However, we have found no differences in 1-year survival between eras, and 1-year survival is an excellent predictor of 5-year survival. Therefore, if there were a difference in survival between eras we would expect to have detected that difference at 1 year.

This leads us to consider alternative reasons for the disconnect between higher pretransplant liver disease severity and unchanged post-OLT outcomes. One possibility is that post-OLT survival is driven by a host of un-measurable factors beyond pre-OLT liver disease severity. It is possible that although the MELD era has increased pre-OLT severity, it has made no impact on the additional un-measurable factors that drive post-OLT survival. Another possibility is that the difference in severity between the pre- and post-MELD eras, although statistically significant, is not clinically relevant. Specifically, the 3.5-point increase in pre-OLT MELD between the pre- and post-MELD eras may be inadequate to translate into a survival difference. Moreover, linking both explanations together, the multiple un-measurable drivers of post-OLT survival may overwhelm the small impact of a 3.5-point increase in MELD on post-OLT survival. Finally, it is also possible that liver transplantation acts as a 'reset phenomenon' in patients with liver disease by abating baseline differences in severity between individuals.

The principal goal underlying the MELD-based policy change was to reduce the number of deaths on the OLT waiting list by preferentially allocating organs to patients at high risk of dying without adversely affecting the post-OLT survival.[11] Our data reveal that cadeveric livers were allocated to the patients most in need and that this outcome did not adversely affect 1-year post-OLT patient or graft survival. Although we did not evaluate the impact of the MELD-based system on outcomes of waiting list patients who did not receive OLT, Freeman *et al.* recently examined this key aspect. The authors reported a 3.5% reduction in waiting list mortality in the post- vs. pre-MELD era. Taken together, our results and the data from Freeman *et al.* indicate the MELD era has achieved its primary goals by allocating cadeveric livers to the sickest patients, and decreasing waiting list mortally without compromising post-OLT survival. However, in order to fully evaluate the impact of the MELD-based system, future research should measure other outcomes including resource utilization and costs between the pre- and post-MELD eras.

Our analysis has several strengths. First, whereas previous reports have measured short-term (3-month) post-OLT outcomes, our analysis follows patients for 1-year post-OLT. This provides a more robust estimate of how the MELD policy has impacted post-OLT survival. Secondly, our analysis relies upon data collected by UNOS. Because the UNOS database is the largest and most comprehensive survey of OLT data in the United States, our analysis is a reliable depiction of outcomes across a range of centres and patients. Thirdly, in order to ensure complete ascertainment of post-OLT mortality, we linked the UNOS data with an external data source (SSDMF) to validate our post-OLT survival data. As a result, our analysis provides an unbiased estimate of how the MELD-based system has impacted outcomes in liver transplantation. Last, we selected the variables for our regression model on the basis of *a priori* disease-specific hypotheses derived from previous research and clinical experience, and this itemization occurred prior to conducting the analysis. In this regard our analysis is hypothesis-driven rather than hypothesis generating, and attempts to capture and adjust for the full range of variable that might affect the relationship between the MELD system and OLT outcomes.

Our analysis has several limitations. First, the data required to calculate MELD scores were present in only 70% of the UNOS sample. However, there is no *a priori* reason to expect systematic over- or under-reporting of the INR, bilirubin, or serum creatinine levels – variables that are required to calculate the MELD score. Therefore, the data appear to be missing at random and their absence is unlikely to impact the validity of our results. Secondly, we relied on the UNOS database for estimates of recipient, donor, and transplant centre characteristics. As data are entered only for listing reasons, absence of data on variables or events does not mean that they did not occur. These limitations in reporting and data entry practices may have resulted in an instrumentation bias in our study, explaining some of the differences in the pre- vs. post-MELD cohorts. Thirdly, our analyses were limited to an assessment of changes in the pre-OLT liver disease severity and post-OLT outcomes in the post-MELD era. In order to fully evaluate the impact of the policy change future research will need to incorporate resource utilization and costs into the analysis.

In conclusion, our analysis of the UNOS liver transplant database reveals that cadaveric livers were allocated to patients with more severe liver disease in the post- vs. the pre-MELD era. Despite the prioritization of sicker patients, the 1-year patient and graft survival are unchanged compared with the pre-MELD era. One possible explanation of this disconnect between the increase in pre-OLT severity and the unchanged post-OLT outcomes is that the impact of the increased severity on post-OLT survival may have been abated by other unmeasurable drivers of post-OLT survival. Our results and the recent data from Freeman *et al.* indicate that the MELD era has achieved its primary goals by allocating cadeveric livers to the sickest patients, and decreasing waiting list mortality without compromising post-OLT survival.

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