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Ethnic and Age Disparities in Outcomes among Liver Transplant Waitlist Candidates

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Abstract

Background: Despite the increasing prevalence of end-stage liver disease in older adults, there is no consensus to determine suitability for liver transplantation (LT) in the elderly. Disparities in LT access exist, with a disproportionately lower percentage of African Americans (AAs) receiving LT. Understanding waitlist outcomes in older adults, specifically AAs, will identify opportunities to improve LT access for this vulnerable population.

Methods: All adult, liver-only white and AA LT waitlist candidates (1/1/2003–10/1/2015) were identified in the Scientific Registry of Transplant Recipients. Age and race categories were defined: younger (age <60) white, younger AA, older white (age ≥60), and older AA. Outcomes were delisting, transplantation, and mortality and were modeled using Fine and Gray competing risks.

Results: Among 101,805 candidates, 58.4% underwent transplantation, 14.7% died while listed, and 21.4% were delisted. Among those delisted, 36.1% died, while 7.4% were subsequently relisted. Both older AAs and older whites were more likely than younger whites to be delisted and to die after delisting. Older whites had higher incidence of waitlist mortality than younger whites (sdHR 1.07; 95%CI:1.01–1.13). All AAs and older whites had decreased incidence of LT, compared with younger whites.

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Conclusions: Both older age and AA race were associated with decreased cumulative incidence of transplantation. Independent of race, older candidates had increased incidences of delisting and mortality following delisting than younger whites. Our findings support the need for interventions to ensure medical suitability for LT among older adults and to address disparities in LT access for AAs.

Introduction:

Due to the rising incidence of nonalcoholic fatty liver disease (NAFLD) and aging of the hepatitis C (HCV) population, there is an increasing prevalence of cirrhosis among older adults in the United States.(1–4) As this population ages, access to transplantation among older adults will become increasingly more important, as liver transplantation is the standard of care for end-stage liver disease (ESLD). These trends are already being realized in clinical practice, with a recent study demonstrating a 2.5-fold increase in the number of liver transplant recipients over the age of 65 years.(5) However, few studies have examined the waitlist outcomes of older adults waitlisted for liver transplantation, specifically since the introduction of the Model for End-Stage Liver Disease (MELD) score-based organ allocation in 2002. One recent analysis, based on best available national data and well-established simulation modeling techniques, predicted patients on the liver transplant waitlist will become older, wait longer, undergo transplantation at a higher MELD score, and have a greater risk for waitlist removals.(6) Despite the aging ESLD population, there are currently no published guidelines or consensus on the upper age limit for liver transplantation.(7) Not suprisingly, there are center and regional variations in liver transplant rates among older adults, which have been found to be independent of the proportion of older adults living in the region.(5, 8) However, barriers in access to liver transplantation can exist at many points along the evaluation process, from referral to transplant centers for waitlist consideration to selection for transplantation.

Moreover, the elderly liver transplant candidate population is not the only population susceptible to disparities in access to liver transplantation. Data from the National Health and Nutrition Examination Survey and cohort studies demonstrated that chronic viral hepatitis, alcoholic liver disease, and NAFLD are more common in ethnic and racial minority communities compared to whites. (9, 10) However, despite the high prevalence of liver disease among African Americans (AAs), AA liver transplant candidates account for a small fraction of the patients on the transplant waiting list(8, 11). Our center previously reported that 14% of 844 liver transplant referrals were AA, despite a 25% AA population served by the hospital. (12) Given the higher prevalence of ESLD among AA as compared to other racial groups, AA patients are likely under-represented. Reasons for the lower rate of liver transplantation among AAs are multifactorial including: late referral, lack of access, personal beliefs, and medical comorbidities. (13, 14) A recent analysis showed that AA patients are listed with higher MELD scores and consequently have shorter waiting times, suggesting that the barriers in access to liver transplantation remain.(15)

Both AAs and older adults face many obstacles throughout the transplant evaluation and waitlist process. Understanding the waitlist outcomes among older adults with ESLD, and specifically older AAs, would allow for the identification of opportunities to both improve

LT access and develop interventions aimed at decreasing disparities. We therefore sought to evaluate the relationship between race/ethnicity, aging and waitlist outcomes among adult liver transplant candidates on a national level. We hypothesized that older AA transplant candidates represent a uniquely vulnerable population due to the synergistic effects of age and race, resulting in lower transplantation rates. We undertook the current study with the following aims: to examine the trends in waitlist outcomes among older adults listed for liver transplant in the United States between 2003 and 2015, and to evaluate the impact of age and race on transplantation, mortality, waitlist removal and subsequent outcomes.

Materials and Methods:

Data Source

This study used data from the Scientific Registry of Transplant Recipients (SRTR). The SRTR data system includes data, submitted by members of the Organ Procurement and Transplantation Network, on all donors, waitlisted candidates, and transplant recipients in the United States. The Health Resources and Services Administration of the US Department of Health and Human Services provides the oversight to the activities of the Organ Procurement and Transplantation Network and SRTR contractors. This study was approved by the Institutional Review Board at the University of Alabama at Birmingham.

Study Population

All adult, liver-only white and AA liver transplant candidates listed between January 1, 2003-October 1, 2015 were identified in SRTR(n=101,805). Multiple simultaneous listings were collapsed. All patients began contributing time at risk at first listing date and continued to do so until the earliest of death, transplant, delisting, or end of study (October 1, 2016).

Outcome Ascertainment

The primary outcome measures were delisting, transplantation, and waitlist mortality. Death indicators were supplemented by linkage to the Social Security Death Master File and by linkage to data from the Centers for Medicare and Medicaid Services. All outcome measures were censored for administrative end of study.

Statistical Analyses

Exploratory Data Analyses—Demographic and clinical characteristics within the cohort were explored initially by frequency and medians. Characteristics were then compared across age and race categories, defined as younger (age < 60 at listing) white, younger AAs, older (age ≥60 at listing) white, and older AAs. Age of 60 years was selected similar to other studies, which defined elderly as ≥60 years, and the age cutoff also allowed for a more robust analysis given the small number of older AAs on the liver waitlist(16, 17). Characteristics were compared using chi-square for categorical variables and Kruskal-Wallis for continuous variables.

Survival Analyses—To account for underlying differences in the rates of delisting, transplant, and waitlist mortality, incidence of outcomes were estimated using Fine and Gray competing risks regression(18). Given the large sample size, covariate selection was

conducted *a priori,* based on clinical relevance. Models were adjusted for the following: age and race in the four previously specified categories, sex, history of abdominal surgery, history of bacterial peritonitis, history of portal vein thrombosis, functional status, diabetes, diagnosis of HCC, willingness to accept an HCV positive donor, MELD score, Body Mass Index (BMI) at listing, history of encephalopathy, history of ascites, hospitalization, hemodialysis, blood type, waitlist status at listing, liver disease etiology classification, and OPTN region. In order to assess progression of liver disease within the cohort, we included MELD score as a time-varying covariate to our statistical models. The largest value between laboratory MELD and MELD derived from exception points, ie, allocation MELD, was used(19). MELD was categorized into the following groups: <15, 15–19, 20–29, 30–39, and 40(20, 21). Primary liver disease etiologies were collapsed based on SRTR diagnosis groupings for risk adjusted models, with the following categories: acute hepatic necrosis, biliary atresia, cholestatic liver disease/cirrhosis, malignancy, metabolic disorders, noncholestatic cirrhosis, and other. Functional status was defined as either no assistance needed with activities of daily living (Karnofsky score of ≥80%), or assistance needed (Karnofsky score of <80%). Multiplicative interaction terms between age and race were examined to assess the statistical significance of any effect modification. Robust standard errors were specified to account for within listing center clustering.

Differences in the incidence of relisting and death after delisting by age and race were further explored in adjusted analyses again using the Fine and Gray competing risks method among those who were delisted, adjusting for the same covariates as the initial models. For both relisting and death after delisting, candidates began contributing time at risk on date of delisting and continued to do so until the earliest of: relisting, death, or end of study. Due to missing data for some of the covariates, such as hospitalization and hemodialysis status, a complete case analysis was performed and reported (n=89,364). Lastly, as a sensitivity analysis, all missing levels of data were coded as such to allow for inclusion in modeling. Inferences were consistent with the presented complete case analyses. All analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC).

Results:

There were 101,805 adult transplant candidates wailisted for liver transplantation between January 1, 2003 and October 1, 2015 who met the inclusion criteria (Table 1). Nearly 30% of the cohort was age 60 years or older, and 11.4% of the waitlist candidates were AA. The majority of candidates were male (65.0%). When functional status was evaluated, over half of the candidates required some assistance with daily activities at the time of listing (56.7%). Overall, 58.4% of the cohort underwent transplantation, 14.7% died on the waitlist, 21.4% were delisted, and the rest of the participants remained on the waitlist. Of the candidates who were delisted, 36.1% died after delisting, while 7.4% were subsequently relisted. The reasons for delisting varied, including candidates not being medically suitable (38.0%), transplantation no longer needed (22.0%), refusal/loss of contact (6.1%), and other reasons (34.0%).

Waitlist Cohort Characteristics Stratified by Age and Race

Characteristics were also compared across age and race categories (Table 1). The majority of the cohort was made up of younger white candidates (61.7%), followed by older white candidates (26.9%). By contrast, younger AAs accounted for 8.5% of the candidates, with older AA only representing 2.9% of the cohort. Therefore, the ratio of younger to older waitlist candidates was 2.3 for whites and 2.9 for AAs. When assessing transplantation, older candidates were less likely to receive a liver transplant (older whites 56.9% and older AA 57.9%) compared with younger whites (61.8%) and younger AAs (62.8%) ($p<0.001$). Compared to their younger counterparts, older candidates also had an increased proportion of waitlist removals (22.1% for older whites and 22.4% for older AAs) and had higher mortality after being removed from the list (40.4% and 40.8% respectively) ($p<0.001$). Older patients were also less commonly relisted for transplant after they were removed from the list, with 4.8% of whites and 3.2% of older AAs relisted, as compared to 8.5% of younger whites and 9.8% of younger AAs ($p<0.001$). The reasons for delisting did vary among the four age and race categories. Older candidates were more commonly delisted for medical unsuitability (49.3% for older whites and 54.9% for older AAs compared with 31.9% for younger whites and 38.9% for younger AAs, $p<0.0001$). Transplant refusal or loss of contact was slightly more prevalent among younger whites (6.2%, compared with 5.9% for all other demographic groups). Furthermore, medical recovery negating the need for liver transplantation was more prevalent among younger AAs and younger whites (24.4% for each), compared with older whites (17.0%)and older AAs (11.7%).

We also observed differences among the age and racial groups on the basis of candidates' disease severity, baseline functional status and other characteristics. While the median MELD score at listing for all candidates was 16, the median MELD score was higher among younger AAs at 19 ($p<0.001$). Although only 20.7% of all candidates were hospitalized at listing, 29.8% of younger AAs were hospitalized at the time they were added to the waitlist. Furthermore, AAs had lower functional status reported, with higher rates of assistance with daily activities needed (58.2% for younger AAs, 58.6% for older AAs, compared with 56.5% and 56.4% of younger and older whites respectively, $p <0.001$). Likewise, Hepatocellular Carcinoma (HCC) was documented in only 7.6% of all candidates, while affecting 16.2% of older AAs ($p<0.001$). With regards to liver disease etiology, acute hepatic necrosis was the most prevalent among younger AAs (9.5%, $p<0.001$). Maligancy as the primary etiology of liver disease was more prevalent among older candidates (Table 1). Alternatively, metabolic disorders were more commonly reported among white candidates compared with AAs, irrespective of age (Table 1). Finally, older AAs had the highest prevalence of willingness to accept HCV+ organs (54.3%, $p<0.001$). Additional classifications of liver disease etiologies by age and race categories were included in Table S1.

Incidence of Transplantation

Based on the Fine and Gray competing risk model, transplantation probability was lower for younger AAs compared with younger whites (Table 2). Additionally, there was a lower incidence of transplantation for older white (subdistribution hazard ratio (sdHR) 0.83; 95%CI: 0.0.80–0.85) and older AA candidates (sdHR 0.76; 95%CI: 0.71–0.82) when

compared to the younger white candidate reference group. Moreover, when comparing the incidence of transplantation among older candidates, older AAs were also less likely than the older whites to undergo transplantation (sdHR 0.92; 95% CI: 0.0.85–1.00).

Independent of age and race/ethnicity, HCC (sdHR 1.08; 95% CI: 1.03–1.13), willingness to accept HCV+ organ (sdHR 1.06; 95% CI: 1.03–1.09), and starting active on the waitlist (sdHR 1.31; 95% CI: 1.21–1.41) were associated with increased incidence of transplantation. However, female sex (sdHR 0.83; 95% CI: 0.81–0.86), and encephalopathy (sdHR 0.86; 95% CI: 0.83–0.89) were associated with decreased incidence of transplantation.

Incidence of Waitlist Mortality

When examining waitlist mortality, older whites had higher incidence of death on the waitlist than younger whites (sdHR 1.07;95%CI: 1.01–1.13) (Table 3). There was no statistically significant difference in waitlist mortality for older AAs compared to younger whites. However, older AAs had lower incidence of waitlist mortality than their older white counterparts (sdHR 0.85; 95%CI: 0.74–0.99).Likewise, younger AAs had lower waitlist mortality cumulative incidence than younger whites (sdHR 0.88; 95%CI: 0.80–0.96).

Incidence of Delisting, Mortality after Delisting

Additionally, older candidates were more likely than younger whites to be removed from the waitlist (Table 4), but there was no statistically significant difference in the risk of delisting between older whites and older AAs (sdHR 1.12; 95% CI: 1.00–1.26). Older candidates also had higher risk of mortality after delisting compared with younger whites who were also delisted (sdHR 1.26; 95% CI: 1.16–1.36 for older whites, and sdHR 1.36;95%CI:1.15–1.59 for older AAs)(Table 5). Again, there was no statistical difference in mortality following delisting among older candidates on the basis of race. The median time to death following delisting was 0.23 years (IQR 0.02–1.11), however the median time to death was shorter among younger AAs (0.19 years, IQR 0.02–1.00) and older AAs (0.17 years, IQR 0.02–0.88). Furthermore, both older whites and older AAs were less likely than younger whites to be relisted after delisting (sdHR 0.59; 95% CI: 0.48–0.71 for older whites, and sdHR 0.34; 95% CI: 0.19–0.61 for older AAs) (Table 5).

Discussion:

The results of this national study demonstrate that transplantation rates and waitlist outcomes differ among liver transplant candidates on the basis of both age and race. Younger AAs had the highest median MELD score at time of waitlist addition, and yet in adjusted competing-risk models, they had lower cumulative incidence of liver transplantation, compared with their white counterparts. Additionallly, both older AA and older white candidates were less likely to undergo transplantation while on the waitlist than younger whites. However, when compared with older whites, older AAs were even more disadvantaged in their likelihood of undergoing transplantation. Interestingly, when assessing waitlist mortality, we found that only older white candidates had statistically higher incidence of mortality while listed when compared to younger candidates. Aside from

these differences, older white and older AA candidates had similar waitlist outcomes. Specifically, compared with their younger white counterparts, both older white and older AA candidates were more likely to be removed from the waitlist and were unlikely to be reactivated once removed. Importantly, we demonstrated that removing an older candidate, regardless of race, from the waitlist is likely a terminal event as they are unlikely to be relisted and are likely to die following delisting.

Our work demonstrated that AAs, irrespective of age, had decreased cumulative incidence of transplantation compared with younger white transplant candidates. However, barriers to transplantation can occur even before patients are added to the waitlist. This study demonstrated that a disproportionately lower percentage of liver waitlist candidates were AA, despite historically high ESLD burden among AAs.(22) These findings suggest that there may be a difference in referral patterns for AA candidates, confirming the results of prior literature.(22) We also found that both older and younger AAs had a higher proportion of candidates hospitalized at the time of listing, which is likely a surrogate for referral with more advanced liver disease. As other studies have shown, delays in transplant evaluation may be due to impaired access and late referral to liver specialists and transplant services.(8, 23–25) Several studies have also demonstrated that AAs are disadvantaged compared to whites in the transplant process, evidenced by inequitable treatment of cirrhosis complications and referral for transplant evaluation with more advanced liver disease and greater disease-related morbidity.(8, 11, 12, 22, 26, 27) Moreover, our finding that AAs have higher median MELD at listing further confirms that they are referred for transplant evaluation with more advanced disease. Although the MELD allocation strategy for livers which prioritizes “sickest first” has lessened the disadvantage associated with later referral for evaluation, disparities still persist.(28) Efforts to improve the timeliness of transplant evaluation may improve overall care for all patients with liver disease, especially since little data exist to aid in the identification of patients who are too sick for transplant evaluation when they present for medical care.

Interestingly, we found that while there was no increased waitlist mortality among older AA compared with younger whites, older whites had higher incidence of waitlist mortality in comparison to their younger counterparts. We also observed that among AA candidates, HCC was more prevalent than among white candidates, particularly in the older cohort. This trend may also reflect a higher degree of selection among older AAs listed for transplantation, as prior literature has demonstrated that candidates with HCC are typically older, more likely to undergo transplantation, and are less likely to die on the waitlist. (29, 30) Likewise, this finding may partially contribute to the low waitlist mortality that we observed among older AAs.

As expected, in this study, older adults were more likely to be removed from the transplant waitlist than younger transplant candidates irrespective of racial background. Following delisting, both older AA and older white adults were more likely to die and less likely to be relisted as transplant candidates. However, prior studies indicate that liver transplantation can be safely performed in low risk older adults. (31–33) Objectively defining low-risk candidates for transplantation is difficult. Functional status, specifically the 6-minute walk distance (6MWD) has been used to identify adults at risk for poor waitlist outcomes.(34, 35)

Additionally, this same study reported that the 6MWD strongly correlated with physical performance after liver transplant, and the authors demonstrated an inverse relationship between exercise capacity and severity of liver disease, independent of liver disease etiology. (34) The Karnofsky Performance Status scale has also been validated in other studies, with poor performance associated with increased risk of mortalilty following liver transplantation (36). Similarly, impaired preoperative cardiopulmonary reserve has been shown to be an accurate predictor of 90-day survival after liver transplantation.(37) Therefore, interventions aimed at maintaining functional status and improving cardiopulmonary status among older transplant candidates may lead to better overall outcomes following transplantation. These findings also highlight the importance of developing actionable strategies to maintain candidates in medically suitable condition for transplantation. It is possible that prehabilitation and interventions to maintain functional status may be helpful to prevent poor waitlist outcomes in older adults and improve posttransplant outcomes.

The large nature of the study allows for assessment of the disparities in access to liver transplantation by age and race on a national level, shedding light on the fact that disparities in access to liver transplantation evaluation persist for AAs. However, this study is not without limitations. This was a retrospective analysis from a large database, and as such we were restricted by the available information and may not have accounted for all potential confounding. However, given the large sample size, we were able to rigorously test for confounding and were not limited in model building by our event rate. Moreover, given the limited granularity of the data utilized, we were not able to account for other factors that may contribute to disparities in liver transplantation and waitlist outcomes among adult liver transplant candidates. For example, although we were able to account for functional status, our data did not reliably capture the candidates' mobility and physical capacity. Similarly, we were unable to determine from the data the reason for delisting. Such information would be helpful when creating interventions aimed at improving access to transplantation among elderly candidates. Similarly, information regarding organ turndown was not available in this study, however, other literature suggests that among US liver waitlist candidates who were delisted or died on the waitlist, around half of the candidates had received at least one organ offer(38). As such, in our cohort, many of those who were delisted or died on the waitlist had likely received and turned down an offer as well, although we are unable to determine if the turndowns differed by age or race.

In conclusion, older adults, including both AA and white candidates, listed for liver transplant represent a uniquely vulnerable population. Our data demonstrate that they were more likely to have poor waitlist outcomes compared to their younger counterparts. Additionally, waitlist removal is likely a terminal event for older adults compared with younger adults listed for liver transplantation. Despite improvements in transplant disparities with the MELD based allocation, disparities in access to transplant services persist for AAs. As candidates for liver transplantation age, it is important to identify reasons for waitlist removal among older adults and implement interventions to help them remain actively listed for transplantation. Similarly, measures are still needed to address disparities in access to liver transplantation for AA candidates.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations:

AA	African American
ESLD	End-stage liver disease
HCV	Hepatitis C Virus
LT	Liver transplantation
MELD	Model of End-Stage Liver Disease
NAFLD	Nonalcoholic fatty liver disease
SRTR	Scientific Registry of Transplant Recipients
sdHR	Subdistribution hazard ratios

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Table 1.

Baseline characteristics and outcomes of liver transplant waitlist candidates between January 1, 2003 and October 1, 2015, overall and stratified by age and race

	All Candidates	Younger White	Younger AA	Older White	Older AA	*P* value
	N=101,805	N=62,822 (61.7)	N=8,698 (8.5)	N=27,378 (26.9)	N=2,907 (2.9)	
	N (%)	N (%)	N (%)	N (%)	N (%)	
Characteristics						
Male	66,124 (65.0)	41,733 (66.4)	4,927 (56.7)	17,638 (64.4)	1,826 (62.8)	<0.001
BMI, Median (IQR)[A]	28 (24–32)	28 (24–32)	28 (24–32)	28 (25–32)	27 (24–31)	<0.001
Prior surgery (abdominal)[B]	39,421 (38.7)	23,526 (37.5)	3,128 (36.0)	11,715 (42.8)	1,052 (36.2)	<0.001
Portal vein thrombosis[B]	4,079 (4.0)	2,421 (3.9)	206 (2.4)	1375 (5.0)	77 (1.9)	<0.001
Encephalopathy[A]	65,168 (64.0)	40,973 (65.2)	5,181 (59.6)	17,401 (63.6)	1,613 (55.5)	<0.001
Ascites[A]	76,032 (74.7)	47,468 (75.6)	6,036 (69.4)	20,533 (75.0)	1,995 (68.6)	<0.001
Diabetes[B]	24,483 (24.5)	12,463 (20.2)	1986 (23.3)	9,053 (33.6)	981 (34.2)	<0.001
HCC [A]	8,051 (7.9)	3,834 (6.1)	639 (7.4)	3,106 (11.3)	472 (16.2)	<0.001
Willing to accept HCV+	40,693 (40.0)	26,279 (41.8)	4,052 (46.6)	8,784 (32.1)	1,578 (54.3)	<0.001
Bacterial peritonitis[B]	5872 (5.8)	3,899 (6.2)	413 (4.8)	1,432 (5.2)	128(4.4)	<0.001
INR, Median (IQR)[A]	1.5 (1.2–2.1)	1.5 (1.2–2.1)	1.7 (1.3–2.4)	1.5 (1.2–2.0)	1.5 (1.2–2.1)	<0.001
Albumin, Median (IQR)[A]	3.0 (2.5–3.5)	3.0 (2.5–3.5)	2.8 (2.3–3.4)	3.1 (2.6–3.6)	3.0 (2.4–3.6)	<0.001
Creatinine, Median (IQR)[A]	1.1 (0.8–1.8)	1.0 (0.8–1.7)	1.2 (0.9–2.3)	1.2 (0.9–1.8)	1.3 (1.0–2.3)	<0.001
Sodium[B]	137 (134–140)	137 (133–140)	137 (134–140)	137 (134–140)	138 (135–140)	<0.001
Bilirubin, Median (IQR)[A]	3.2 (1.5–8.8)	3.4 (1.6–9.4)	4.7 (1.6–16.2)	2.7 (1.4–6.3)	2.3 (0.9–7.3)	<0.001
Hospitalized[C]	17,781 (20.7)	11,297 (21.0)	2,203 (29.8)	3,806 (17.0)	475 (20.7)	<0.001
Hemodialysis[C]	5,244 (6.4)	3,060 (6.0)	728 (10.3)	1,187 (5.5)	269 (12.1)	<0.001
MELD at listing	16 (11–22)	16 (11–22)	19 (13–28)	15 (11–20)	16 (10–23)	<0.001
Primary ESLD etiology [A]						<0.001
Other	8,387 (8.2)	5,532 (8.8)	1065 (12.3)	1,603 (5.9)	187 (6.4)	
Acute Hepatic Necrosis	4,758 (4.7)	3,238 (5.2)	823 (9.5)	583 (2.1)	114 (3.9)	
Biliary Atresia	246 (0.2)	196 (0.3)	46 (0.5)	4 (0.01)	0	

	All Candidates	Younger White	Younger AA	Older White	Older AA	*P* value
Cholestatic Liver Disease/ Cirrhosis	8,172 (8.0)	4,901 (7.8)	873 (10.0)	2262 (8.3)	136 (4.7)	
Malignancy	8,291 (8.1)	4,072 (6.5)	641 (7.4)	3,170 (11.6)	408 (14.0)	
Metabolic Disorders	2,007 (2.0)	1,374 (2.2)	54 (0.6)	570 (2.1)	9 (0.3)	
Noncholestatic cirrhosis	69,934 (68.7)	43,502 (69.3)	5,194 (59.7)	19,185 (70.1)	2,053 (70.6)	
Functional status[B]						
No Assistance	40,866 (43.3)	25,176 (43.5)	3,326 (41.8)	11,217 (43.6)	1,147 (41.4)	0.005
Assistance Needed	53,455 (56.7)	32,721 (56.5)	4,626 (58.2)	14,487 (56.4)	1,621 (58.6)	
Blood Type						
A	39,981 (39.3)	25,880 (41.2)	2,226 (25.6)	11,126 (40.6)	749 (25.8)	<0.001
B	12,286 (12.1)	6,828 (10.9)	1,857 (21.4)	3,022 (11.0)	579 (19.9)	
AB	3,983 (3.9)	2,408 (3.8)	345 (4.0)	1,098 (4.0)	132 (4.5)	
O	45,555 (44.8)	27,706 (44.1)	4,270 (49.1)	12,132 (44.3)	1,447 (49.8)	
Outcome						
Transplant	59,449 (58.4)	36,731 (61.8)	5,461 (62.8)	15,575 (56.9)	1,682 (57.9)	<0.001
Died on waitlist	14,933 (14.7)	9,114 (14.5)	1,183 (13.6)	4,242 (15.5)	394 (13.6)	
Delisted	21,813 (21.4)	13,404 (21.3)	1,702 (19.6)	6,057 (22.1)	650 (22.4)	
Died after delisting[D]	7,868 (36.1)	4,559 (34.0)	598 (35.1)	2,446 (40.4)	265 (40.8)	<0.001
Relisted after delisting[D]	1,613 (7.4)	1,136 (8.5)	167 (9.8)	289 (4.8)	21 (3.2)	

[A] Missing for less than 1%;

[B] Missing for <10%;

[C] Missing for 10–20%;

[D] Among delisted only

Table 2.

Fine and Gray model with adjusted[1] subdistribution hazard ratios (sdHRs), 95% Confidence Intervals (CIs), and *p* values for likelihood of transplant

	sdHR	**95% CI**	***P* value**
Characteristic			
Younger White	Ref		
Younger AA	0.92	0.88–0.97	0.001
Older White	0.83	0.80–0.85	<0.0001
Older AA	0.76	0.71–0.82	<0.0001
Female	0.83	0.81–0.86	<0.0001
Previous abdominal surgery	1.03	1.00–1.06	0.04
Bacterial peritonitis	0.97	0.91–1.03	0.28
Portal vein thrombosis	1.10	1.02–1.17	0.01
Functional status: Assistance Needed	0.89	0.86–0.91	<.0001
Diabetes	0.99	0.96–1.02	0.44
HCC	1.08	1.03–1.09	0.002
Willing to accept HCV+	1.06	1.03–1.09	<.0001
BMI > 30	1.07	1.04–1.10	<0.0001
Encephalopathy	0.86	0.83–0.89	<0.0001
Ascites	1.25	1.20–1.29	<0.0001
Active at listing	1.31	1.21–1.41	<0.0001
MELD category[2]			
<15	Ref	Ref	
15–19	1.88	1.85–1.92	<0.0001
20–29	2.79	2.74–2.85	<0.0001
30–39	4.14	4.00–4.29	<0.0001
40	2.60	2.47–2.73	<0.0001
ESLD etiology			
Other	Ref	Ref	
Acute Hepatic Necrosis	0.84	0.77–0.92	0.0002
Biliary Atresia	1.48	1.11–1.95	0.01
Cholestatic Liver Disease/Cirrhosis	1.59	1.49–1.71	<0.0001
Malignancy	1.07	1.03–1.13	0.003
Metabolic Disorders	1.41	1.26–1.56	<0.0001
Non-cholestatic cirrhosis	1.05	1.00–1.11	0.08

[1] Also adjusted for OPTN region, blood type

[2] Time varying allocation MELD

Table 3.

Fine and Gray model with adjusted[1] subdistribution hazard ratios (sdHRs), 95% Confidence Intervals (CIs), and *p* values for likelihood of waitlist mortality

	sdHR	***95%CI***	***P value***
Characteristic			
Younger White	Ref		
Younger AA	0.88	0.80–0.96	0.01
Older White	1.07	1.01–1.13	0.02
Older AA	0.91	0.79–1.05	0.21
Female	1.17	1.11–1.23	<.0001
Previous abdominal surgery	1.00	0.95–1.05	0.90
Bacterial peritonitis	0.93	0.85–1.03	0.17
Portal vein thrombosis	0.85	0.75–0.97	0.02
Functional status: Assistance Needed	0.78	0.74–0.83	<0.001
Diabetes	1.16	1.10–1.23	<0.001
HCC	0.67	0.59–0.75	<0.001
Willing to accept HCV+	1.12	1.06–1.18	<0.001
BMI > 30	1.05	1.06–1.11	0.05
Encephalopathy	1.89	1.77–2.02	<0.001
Ascites	1.35	1.25–1.46	<0.001
Active at listing	1.22	1.06–1.40	0.01
MELD category[2]			
<15	Ref	Ref	
15–19	1.49	1.45–1.53	<0.001
20–29	1.14	1.09–1.18	<0.001
30–39	1.39	1.32–1.47	<0.001
40	1.88	1.76–2.01	<0.001
ESLD etiology			
Other	Ref	Ref	
Acute Hepatic Necrosis	0.74	0.62–0.87	0.0002
Biliary Atresia	1.02	0.61–1.71	0.95
Cholestatic Liver Disease/Cirrhosis	0.91	0.80–1.04	0.16
Malignancy	0.56	0.48–0.65	<0.001
Metabolic Disorders	0.81	0.67–1.00	0.05
Non-cholestatic cirrhosis	0.91	0.82–1.01	0.06

[1]Also adjusted for OPTN region, blood type

[2]Time varying allocation MELD

Table 4.

Fine and Gray model with adjusted[1] subdistribution hazard ratios (sdHRs), 95% Confidence Intervals (CIs), and p values for likelihood of delisting

	sdHR	*95%CI*	*P value*
Characteristic			
Younger White	Ref		
Younger AA	0.99	0.91–1.07	0.74
Older White	1.12	1.07–1.17	<.0001
Older AA	1.25	1.12–1.40	0.0001
Female	1.15	1.10–1.20	<.0001
Previous abdominal surgery	0.96	0.92–1.01	0.10
Bacterial peritonitis	0.86	0.78–0.95	0.003
Portal vein thrombosis	1.17	1.05–1.30	0.01
Functional status: Assistance Needed	0.96	0.92–1.00	0.04
Diabetes	0.98	0.94–1.03	0.45
HCC	0.73	0.67–0.79	<.0001
Willing to accept HCV+	0.90	0.86–0.94	<.0001
BMI > 30	0.95	0.91–0.99	0.01
Encephalopathy	0.99	0.94–1.04	0.63
Ascites	0.71	0.67–0.75	<.0001
Active at listing	0.83	0.75–0.92	0.001
MELD category[2]			
<15	Ref	Ref	
15–19	1.00	0.98–1.03	0.76
20–29	0.57	0.56–0.59	<.0001
30–39	0.44	0.42–0.47	<.0001
40	0.37	0.35–0.40	<.0001
ESLD etiology			
Other	Ref	Ref	
Acute Hepatic Necrosis	1.29	1.14–1.46	<0.0001
Biliary Atresia	0.54	0.32–0.90	0.02
Cholestatic Liver Disease/Cirrhosis	0.64	0.57–0.71	<0.0001
Malignancy	0.93	0.84–1.04	0.23
Metabolic Disorders	0.56	0.46–0.68	<0.0001
Noncholestatic cirrhosis	1.07	0.98–1.16	0.14

[1] Also adjusted for OPTN region, blood type

[2] Time varying allocation MELD

Table 5.

Fine and Gray models with adjusted[1] subdistribution hazard ratios (sdHRs), 95% Confidence Intervals (CIs), and *p* values for likelihood of mortality after delisting and relisting

	Mortality after Delisting		***Relisting***	
Demographics	***sdHR (95%CI)***	***P value***	***sdHR (95%CI)***	***P value***
Younger White	Ref		Ref	
Younger AA	0.95 (0.82–1.10)	0.49	1.08 (0.85–1.37)	0.55
Older White	1.26 (1.16–1.36)	<0.0001	0.59 (0.48–0.71)	<0.0001
Older AA	1.36 (1.15–1.59)	0.0002	0.34 (0.18–0.61)	0.0004

[1]Adjusted for candidate race and age at listing, gender, history of abdominal surgery, history of bacterial peritonitis, history of portal vein thrombosis, functional status, history of diabetes, diagnosis of hepatocellular carcinoma, willingness to accept a Hepatitis C positive organ, time-varying MELD allocation score, body mass index (BMI) at listing, history of encephalopathy, history of ascites, active status at waitlisting, blood type, ESLD etiology, and OPTN region