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Race/ethnicity is associated with ABO-nonidentical liver transplantation in the United States

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Abstract

United Network for Organ Sharing (UNOS) policies allow for ABO-nonidentical liver transplantation (LT) in candidates with Model for End-Stage Liver Disease (MELD) scores greater than 30. Previous studies showed ABO-nonidentical LT resulted in an 18% and 55% net gain in livers for B and AB candidates. These results suggested that the current liver ABO allocation policies may need refinement. There are, however, strong associations between ABO blood groups and race/ethnicity. We hypothesized that race/ethnicity is associated with ABO-nonidentical LT and that this is primarily influenced by recipient ABO status. We examined non-status 1 adult candidates registered between July 1, 2013, and December 31, 2015. There were 27 835 candidates (70% non-Hispanic White, 15% Hispanic, 9% Black, 4% Asian, 1% Other/Multiracial). A total of 11 369 underwent deceased donor LT: 93% ABO identical, 6% ABO compatible, and 1% ABO incompatible. Black and Asian race/ethnicity were associated with increased likelihoods of ABO-nonidentical LT. Adjustment for disease etiology, listing MELD, transplant center volume, and UNOS region did not alter this association. Stepwise inclusion of recipient ABO status did eliminate this significant association of race/ethnicity with ABO-nonidentical LT. Blacks and Asians may be advantaged by ABO-nonidentical LT, and we suspect that changes to the existing policies may disproportionately impact these groups.

Keywords

ABO; allocation; health disparities; race/ethnicity

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CONFLICT OF INTEREST

The authors of this manuscript have no conflict of interests to disclose as described by Clinical Transplantation.

AUTHORS' CONTRIBUTIONS

Jin Ge: Contributed to study concept and design, performed analysis and interpretation of data, drafted the manuscript, critically revised the manuscript for important intellectual content, and performed statistical analysis; John P. Roberts: Contributed to study concept and design, performed interpretation of data, and critically revised the manuscript for important intellectual content; Jennifer C. Lai: Contributed to study concept and design and acquisition of data, performed analysis and interpretation of data, drafted the manuscript, critically revised the manuscript for important intellectual content, obtained funding, and performed study supervision.

1 | INTRODUCTION

Allocation for orthotopic liver transplantation (LT) in the United States is governed by a set of policies propagated by the United Network for Organ Sharing (UNOS), which administers the Organ Procurement and Transplantation Network (OPTN) on behalf of the United States Department of Health and Human Services. Since 2002, the primary unit by which patients are prioritized for nonemergent LT is the Model for End-Stage Liver Disease (MELD) score.[1] Given that the differential distribution of ABO blood types in the United States,[2] UNOS/OPTN Policy 9.6 makes explicit allowances for ABO-nonidentical LT for emergent and nonemergent candidates with MELD scores greater than 30 (Table 1).[1]

Previous studies demonstrated that ABO-nonidentical LT, defined as both ABO compatible and ABO incompatible, resulted in a net gain of livers available for blood type B and AB LT waitlist candidates, on the magnitude of 18% and 55%, respectively.[3] In contrast, blood type O and A waitlist candidates are disadvantaged[4] with a total of 6% and 2% net loss in livers available to them, respectively, under the current allocation rules.[3] These results suggested that the current ABO allocation policies may require deliberate reconsideration to maintain equitable distribution of scarce organs.

Additional research, however, has also demonstrated that racial and ethnic minorities, specifically persons of Black and Asian race/ethnicities, represent a greater proportion of ABO blood types B and AB, the two blood types that receive a net gain in livers from ABO-nonidentical LT.[2] It follows that any refinement of the current ABO allocation policies may have a disproportionate effect on racial and ethnic minorities, some of whom were historically disadvantaged in transplantation medicine.[5,6] We hypothesized that race/ethnicity is associated with ABO-nonidentical transplantation in the liver transplant candidate population–and that this association is largely explained by differences in ABO distribution among racial/ethnicity group, and not by any other clinical or demographic variables. In this study, therefore, we aimed to characterize the probability of ABO-nonidentical LT by race/ethnicity.

2 | MATERIALS AND METHODS

2.1 | Subjects

We analyzed data from the UNOS/OPTN Standard Transplant Analysis and Research (STAR) files as of March 31, 2016,[7] on all adult (age greater than or equal to 18 year) non-status 1 candidates newly registered on the waitlist from July 1, 2013 (after the implementation of Share-35),[8] through December 31, 2015 (before implementation of MELD–Sodium (MELDNa) score for prioritization).[8,9] We specifically chose this time period (post-Share-35 and pre-MELDNa) isolate the study population from major allocation system changes that may have confounded our analyses. Candidates listed as status 1A were excluded as their transplantation teams' motivation to accept an ABO-nonidentical liver may differ from those who were not listed for fulminant hepatic failure.

2.2 | Data classifications

Baseline demographic variables included age, sex, and race/ethnicity. Baseline clinical variables included recipient ABO status, etiology of liver disease, exception points granted, laboratory MELD score at listing, and UNOS region of transplantation. Race/ethnicity was classified as non-Hispanic White, Hispanic, Black, Asian, or Other/Multiracial. These classifications were recorded on the transplant recipient registration forms or on UNet by the transplant center at the time of registration.[10] Race and ethnicity designations were supplied by each transplant center based on the patient's self-report or as assessed by the transplant coordinator in accordance with guidelines from the Office of Management and Budget Directive.[11] According to UNOS conventions, Hispanic/Latino took precedence over all other racial/ethnic categories.

Donor-recipient ABO matching was categorized as follows: "ABO identical" if the recipient received a liver with the exact same ABO blood type; "ABO compatible" if a blood type A, B, or AB recipient received a liver from blood type O donor or a blood type AB recipient received a liver from a blood type O, A, or B donor; and "ABO incompatible" from all other combinations. "ABO nonidentical" was then defined as a combination of ABO-compatible and ABO-incompatible matching at LT.

UNOS regions were classified by their median allocation MELD score at transplant: <28 were categorized as "Low" (UNOS Regions 3, 8, 10, and 11), 28–30 were categorized as "Medium" (UNOS regions 2 and 8), and >30 were categorized as "High" (UNOS regions 1, 4, 5, 7, and 9). Listing centers were classified by their volume during the study period of July 1, 2013, through December 31, 2015: centers that conducted less than 38 transplants (bottom third in volume) were categorized as "Low," centers that conducted between 38 and 94 transplants (middle third in volume) were categorized as "Medium," and centers with greater than 94 transplants (top third in volume) were categorized as "High."

2.3 | Statistical analyses

Clinical characteristics and laboratory data were summarized by medians and interquartile ranges (IQR) for continuous variables or number (%) for categorical variables. Comparisons between groups were performed using chi-square and Kruskal-Wallis tests, when appropriate. The primary outcome was ABO-nonidentical LT. Patients who remained on the waitlist after December 31, 2015, who received living donor LT, and who were removed from the waiting list for nonmedical reasons (defined as "condition improved," "other," "refused transplant," "transferred to another center," and "unable to contact candidate") were censored from the analyses.

The risk of ABO-nonidentical transplantation was evaluated using the competing risks regression with the Fine-Gray model, with ABO-identical LT and death on the waitlist being treated as competing events.[12,13] The covariables that we evaluated were race/ethnicity, age, sex, recipient ABO status, etiology of liver disease (categorized as chronic hepatitis C, alcohol, nonalcoholic fatty liver disease, autoimmune/cholestatic disease, chronic hepatitis B, and other), listing with exception points, laboratory MELD score at listing, listing center volume, and region of listing. All covariables in univariable analyses, regardless of *P*-value,

were evaluated for inclusion in the final multivariable models to predict our outcome. We used purposeful selection of covariables in multivariable models to identify factors that may have confounded or mediated observed associations between race/ethnicity and the outcome. Covariables that changed the coefficients of race/ethnicity by >20% after inclusion were considered strong confounders or mediators.[14] To determine the baseline level of disparities, we extended the multivariable methods described above to evaluate the risk of ABO-identical LT as well.

Cumulative incidence function (Nelson-Aalen) of ABO-nonidentical and ABO-identical LT by race/ethnicity was then calculated. Two-sided *P* values <.05 were considered statistically significant. Analyses were performed using STATA statistical software, version 13.0 (StataCorp, College Station, TX, USA). The institutional review board at the University of California, San Francisco, approved this study.

3 | RESULTS

3.1 | Characteristics of the waitlist cohorts

Baseline characteristics of the 27 835 candidates registered on the LT waitlist during the study period are displayed in Table 2. Of the waitlist candidates, 70% were non-Hispanic White, 15% Hispanic, 9% Black, 4% Asian, and 1% Other/Multiracial. Median age at listing was similar among the different races/ethnicities. Black and Other/Multiracial candidates were more likely to be female (both 41% vs 34% in non-Hispanic Whites). Blacks were more likely to have chronic hepatitis C as the indication for listing (49% vs 33% in non-Hispanic Whites). Black and Asian candidates were more likely to have ABO blood types of B (22% and 28%, respectively) and AB (4% and 9%, respectively).

Asian candidates had lower laboratory MELD scores at listing (13 vs 16 in non-Hispanic Whites), higher albumin (3.4 g/dL vs 3.1 g/dL in non-Hispanic Whites), lower rates of moderate ascites (14% vs 24% in non-Hispanic Whites), and lower rates of encephalopathy (32% vs 58% in non-Hispanic Whites). Asian candidates were also more likely to have hepatocellular carcinoma exception points (34% vs 21% in non-Hispanic Whites). Hispanic, Asian, and Other/Multiracial candidates predominated the waitlist in “High” MELD regions (UNOS regions 1, 4, 5, 7, and 9), defined as median MELD at transplant >30 vs non-Hispanic White and Black candidates. Hispanics and Other/Multiracial candidates were more likely to be listed at medium-volume centers (35% and 39%, respectively, vs 31% in non-Hispanic Whites). Blacks were more likely to be listed at high-volume centers (68% vs 62% in non-Hispanic Whites).

3.2 | ABO-nonidentical transplantation vs ABO-identical transplantation

A total of 11 369 patients underwent deceased donor LT: 10 556 (93%) were ABO identical, 662 (6%) were ABO compatible, and 151 (1%) were ABO incompatible (Table 3). Of the 813 ABO-nonidentical LTs, 44% (359) were O → B, 17% (139) A → O, 15% (121) B → AB, 12% (99) A → AB, 10% (78) O → A, and 2% (17) were of other combinations. Among the 139 blood type O recipients who received a liver from a blood type A donor, 98% (136) were from an A2 donor.

ABO-nonidentical LT occurred more frequently in Blacks (10% of all those transplanted), Asians (11%), and Other/Multiracial candidates (10%) compared to non-Hispanic Whites (7%). A greater proportion of ABO-nonidentical LT recipients were non-White (35%) vs those who received ABO-identical transplants (29%). Black waitlist candidates were more likely to be transplanted at 6 months and at 1 year compared to all other races/ethnicities while Hispanic and Asian waitlist candidates were least likely to be transplanted at 6 months and at 1 year for all types of transplants (Figure 1). The cumulative incidence of ABO-nonidentical and ABO-identical transplantations is shown in Figure 2A,B, respectively.

3.3 | Associations between race/ethnicity and ABO-nonidentical transplantation

In univariable competing risks analysis, Black and Asian race/ethnicity were associated with a significantly increased likelihood of ABO-nonidentical LT (Table 4). Adjustment for age, gender, etiology of liver disease, MELD exception points, laboratory MELD scores at listing, and listing center volume reduced the subhazard ratio (sHR) for Blacks to 1.30 (95% confidence interval [CI] 1.06–1.62, P=.013) and increased the sHR for Asians to 1.63 (95% CI 1.18–2.25, P=.003), but did not change the overall finding that race/ethnicity was associated with ABO-nonidentical LT (Table 5, Model 1). Adjustment for UNOS region of listing (low, medium, or high median MELD at transplantation) did not significantly change the sHR for the association between race and ABO-nonidentical LT (Table 5, Model 2).

We then examined the impact of recipient ABO blood group on the association between race/ethnicity and ABO-nonidentical LT. In our second multivariable model (Table 5, Model 2), we showed that the association between race/ethnicity with ABO-nonidentical LT was still significant even after adjusting for clinical factors and UNOS regions (sHR 1.30, 95% CI 1.05–1.61, P=.016 for Blacks and sHR 1.70, 95% CI 1.22–2.36, P=.001 for Asians). Stepwise inclusion of recipient ABO status into our multivariable model (Table 5, Model 3) eliminated this previously statistically significant association of Black and Asian races with ABO-nonidentical LT (sHR 0.82, 95% CI 0.65–1.01, P=.067 for Blacks and sHR 0.72, 95% CI 0.51–1.03, P=.074 for Asians).

To determine the baseline level of disparities, we also conducted a similar multivariable analysis to evaluate the association between race/ethnicity and ABO-identical LT. Based on this analysis, Black, Hispanic, and Asian candidates were less likely than non-Hispanic Whites and Other/Multiracial candidates to receive an ABO-identical LT. These differences, however, were driven by the recipient's region of listing (eg, in "Low," "Medium," or "High" MELD regions) and not by the recipient's ABO status.

4 | DISCUSSION

This study uses national data from July 1, 2013, through December 31, 2015 (after the implementation of Share-35 and prior to the introduction of MELDNa), to examine the association of race/ethnicity with ABO-nonidentical LT in the United States. We found that Blacks and Asians who were listed for LT in the United States during the study period had higher probability of receiving an ABO-nonidentical transplant. The distributions of type B and AB blood among Black and Asian candidates in our study population were similar to

those previously documented by Garratty et al.'s study–in which 20% of Blacks and 25% of Asians had blood type B, and 4% of Blacks and 7% of Asians had blood type AB.[2]

In both the Black and Asian cohorts, the increased sHR of receiving an ABO-nonidentical LT was strongly affected by recipient ABO status. The increased sHR ratio in Blacks was also affected by poorer clinical status at listing (as indicated by higher initial laboratory MELD scores), but not to the extent of recipient ABO status. While the link between race/ethnicity and ABO-nonidentical LT was previously implied due to the association between race/ethnicity and ABO distribution[2]–this is the first rigorous demonstration of how ABO distributions within different racial/ethnic groups may explain differential propensities in receiving an ABO-nonidentical LT. In addition, our study showed that the link between race/ethnicity and ABO-nonidentical LT may only be minimally affected by other demographic or clinical variables, such as listing center volume or listing region.

Our study does show that Blacks had more severe liver disease than non-Hispanic Whites at the time of listing, which is consistent with previous research.[15,16] Given that Blacks historically have had reduced access compared to non-Hispanic Whites for a number of medical therapies, including orthotopic LT,[16] the current ABO allocation policy represents an important mechanism for early access to orthotopic LT for historically disadvantaged racial/ethnic groups.

When viewed from a strictly ABO allocation point of view, we found that the vast majority of ABO-nonidentical transplantations were due to O livers being transplanted in recipients of other blood types (55%). The greatest shifting of O livers was to blood type B recipients–359 (44%) of the 813 ABO-nonidentical transplantations were of this categories. Although the introduction of the MELD allocation system in 2002 reduced some of the disadvantages experienced by group O candidates,[17] our study is consistent with our prior report that showed a net loss of livers for O candidates due to ABO-nonidentical LT.[3]

One notable finding is the prevalence of A2 mismatch LTs during the study time period: 137 (17%) of the 813 ABO-nonidentical LTs were A2 → O. The use of A2 grafts for ABO-incompatible transplantation has been well established in the renal transplantation literature.[18,19] Recent modifications to the Kidney Allocation System in 2014 explicitly permitted the allocation of A2/A2B → B kidneys in an effort to expand access to minority populations.[20,21] In the LT literature, a 2012 retrospective study of the UNOS database of A2 → O ABO-nonidentical LT showed that A2 → O mismatches to be safe with similar patient and graft survival to O → O ABO-identical LT.[22] The acceptability of A2 → O ABO-incompatible transplantation has also been independently demonstrated in Europe and Asia.[23–25] When we analyzed the distribution of A2 → O transplantation, we found significant regional variation with most of these operations taking place in regions 5 (23%), 2 (14%), 11 (13%), and 3 (10%). These regions were not necessarily the regions with the highest median MELD scores at LT, indicating center-dependent variations in the adoption of A2 → O LT.

This study has several limitations. First, this study relied on UNOS registry data for classification of race/ethnicity, so there is potential for misclassification of this predictor variable, as this variable was either self-reported or assessed by the transplant coordinator.

However, given that the proportion of race/ethnicities in our cohort paralleled previously reported distributions of race/ethnicities by ABO blood type,[2] we feel that misclassification of race/ethnicity did not occur on a large enough scale to significantly impact our results.

Second, large administrative registry analyses can be impacted by missing data; however, our primary predictors of interest included race/ethnicity and ABO blood type and our primary outcome included ABO-nonidentical LT, both of which were missing in less than 0.5% of observations. Lastly, this study only assessed patients who were listed and ultimately underwent LT, but does not allow for any definitive conclusions surrounding access to transplantation among minorities traditionally underserved by the healthcare system.[5,6]

Given our findings that Asians and Blacks, in particular, were *advantaged* by ABO-nonidentical LT, we suspect that these minority populations will be sensitive to any changes or refinements to the current ABO allocation policies. In the 2014 Kidney Allocation System, allocation of A2/A2B blood group kidneys to blood type B recipients has resulted in greater access to kidneys by racial/ethnic minorities.[20,21] Given this, it stands to reason that any changes to the current liver ABO allocation policy in this particular direction may further improve racial/ethnic minorities' access to LT.

Despite these limitations, our study raises important issues surrounding ABO-nonidentical LT by demonstrating the direct association between race/ethnicity with ABO-nonidentical transplantation. Any alterations to the current ABO allocation policy will most likely disproportionally impact Black and Asian candidates, who have been shown above to be the most likely to undergo ABO-nonidentical LT. Conversely, it is not for certain that alterations to the current policy would help candidates of other ethnic groups. Although UNOS Policy 9.6.C and 9.6.D gives the transplant community a framework for ABO-nonidentical LT to occur, we currently still do not understand the most common cause for an ABO-nonidentical graft to be actively selected over an ABO-identical graft. This will be the focus of our next investigation.

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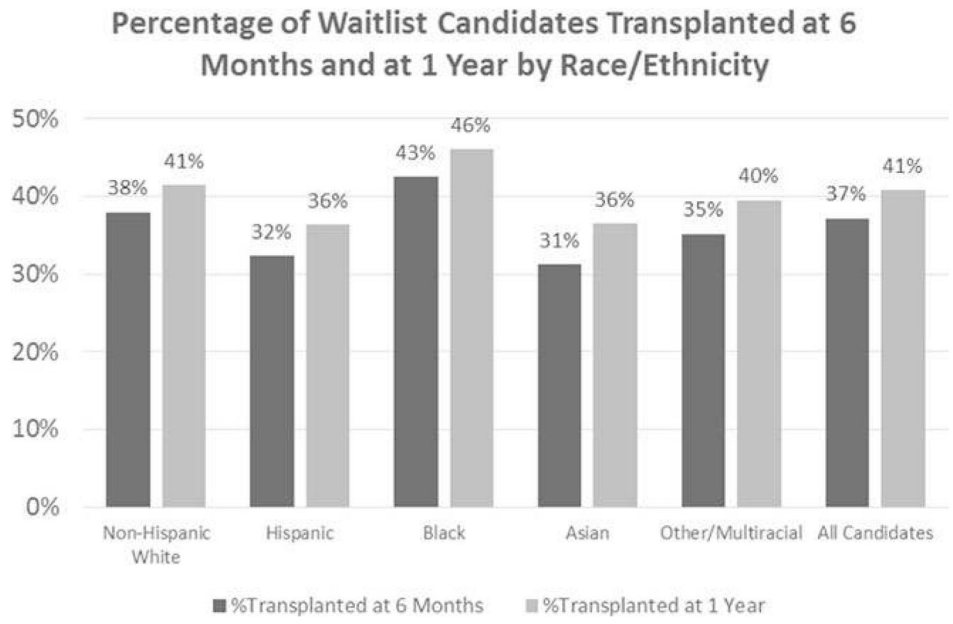

FIGURE 1.

Percentage of waitlist candidates transplanted at 6 months and at 1 year by race/ethnicity for all types of transplants

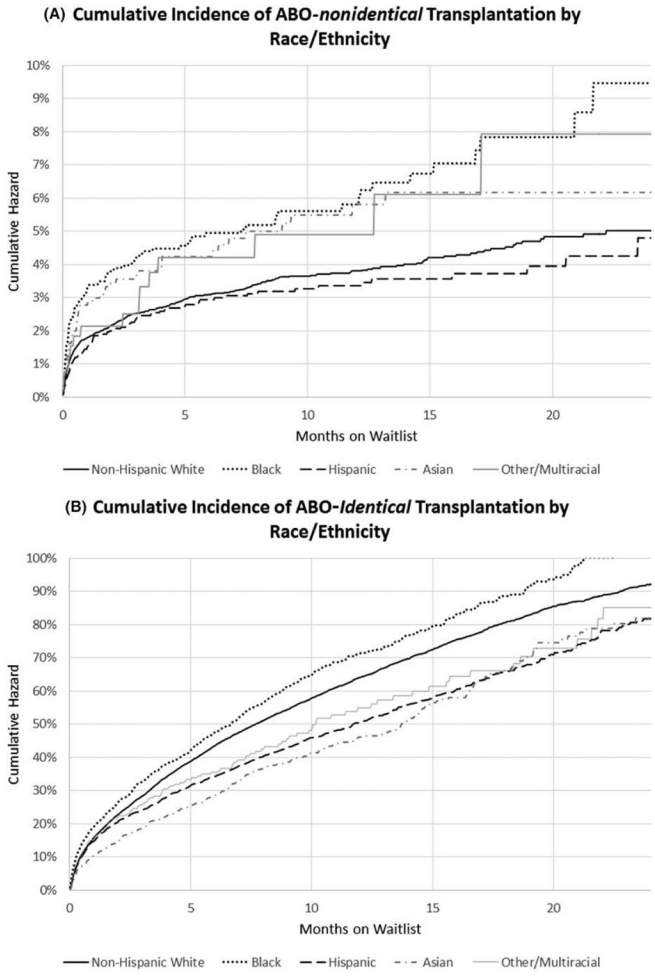

FIGURE 2.

(A) Cumulative hazard of ABO-nonidentical transplantation and (B) ABO-identical transplantation by race/ethnicity

TABLE 1

UNOS/OPTN Policies 9.6.C and 9.6.D

9.6.C–Allocation of livers by blood type
Livers from blood type O deceased donors may be offered to any of the following
Status 1A and 1B candidates
Blood type O candidates
Blood type B candidates with a MELD or PELD score ≥ 30
Any remaining blood type compatible candidates once the blood type O and B candidates on the match run have been exhausted at the regional and national levels
9.6.D–Sorting within each classification
Within each status 1A allocation classification, candidates are sorted in the following order
Total points, highest to lowest (waiting time points, plus blood type compatibility points)
Total waiting time at status 1A (highest to lowest)
Within each status 1B allocation classification, candidates are sorted in the following order
Total points (highest to lowest)
Total waiting time at status 1B (highest to lowest)
Within each allocation MELD or PELD score classification, candidates with a score ≤ 6 are sorted in the following order
Identical blood types, compatible blood types, then incompatible blood types
Total waiting time (highest to lowest)
Then those waiting list positions assigned to candidates with a MELD or PELD score ≤ are redistributed between the pediatric candidates, according to their PELD or MELD score (highest to lowest)
Within each allocation classification, all other candidates are sorted in the following order
MELD/PELD score (highest to lowest)
Identical blood types, compatible blood types, then incompatible blood types
Waiting time at the current or higher MELD or PELD score (highest to lowest)
Total waiting time (highest to lowest)

OPTN, Organ Procurement and Transplantation Network; MELD, Model for End-Stage Liver Disease; PELD, Pediatric-End-State Liver Disease.

TABLE 2

Baseline characteristics of the 27 835 liver transplantation candidates listed from July 1, 2013, through December 31, 2015

	Race/ethnicity				
	Non-Hispanic White	**Black**	**Hispanic**	**Asian**	**Other**
Waitlist candidates, n (% of total)	19 418 (70)	2587 (9)	4193 (15)	1222 (4)	415 (2)
Median age (IQR)	58 (51–63)	57 (49–62)	57 (50–62)	58 (50–64)	56 (49–61)
Sex, female, % cohort	34	41	37	34	41
Recipient ABO Status					
O, % cohort	44	48	57	36	49
A, % cohort	41	26	31	27	36
B, % cohort	11	22	10	28	12
AB, % cohort	4	4	2	9	3
Etiology of liver disease					
Chronic hepatitis C, % cohort	33	49	37	25	35
Alcohol, % cohort	21	8	22	8	22
NAFLD, % cohort	18	3	14	6	16
Autoimmune/cholestatic, % cohort	10	18	9	6	10
Chronic hepatitis B, % cohort	1	4	1	33	3
Other, % cohort	16	18	17	21	15
Exception points					
Hepatocellular carcinoma, % cohort	21	24	23	34	23
Other, % cohort	13	12	12	19	12
Median laboratory MELD at listing (IQR)	16 (11–22)	18 (11–25)	16 (11–23)	13 (8–20)	16 (11–22)
Other clinical characteristics					
Albumin at listing, g/dL (IQR)	3.1 (2.7–3.6)	3.0 (2.5–3.6)	3.1 (2.6–3.5)	3.4 (2.8–4.0)	3.0 (2.6–3.5)
Sodium at listing, mEq (IQR)	137 (133–139)	137 (135–140)	137 (134–139)	138 (135–140)	137 (134–139)
% Moderate ascites at listing	24	20	23	14	20
% Encephalopathy at listing	58	46	54	32	61
Median waitlist days (IQR)	129 (35–314)	112 (26–284)	144 (37–346)	170 (50–367)	139 (39–317)
Listing center volume					

	Race/ethnicity				
	Non-Hispanic White	**Black**	**Hispanic**	**Asian**	**Other**
Low (#txp<38 during study period), % cohort	7	7	8	9	12
Medium (#txp>38 and<94), % cohort	31	25	35	29	39
High (#txp>94), % cohort	62	68	57	61	49
Region					
Low MELD (median <28 at txp), % cohort	42	39	20	17	29
Medium MELD (median 28–30), % cohort	17	24	7	16	14
High MELD (median >30), % cohort	41	36	73	67	57
Total transplanted, % waitlist	43	47	38	37	40
Death or too sick, % waitlist	15	15	18	14	16
Removed for other reasons, % waitlist	5	5	6	6	6
Remained on waitlist, % waitlist	36	33	38	43	38

MELD, Model for End-Stage Liver Disease.

Data are shown as median (interquartile range) or percentage.

TABLE 3

ABO matching of 11 369 candidates in the study population who underwent liver transplantation by race/ethnicity

	Race/Ethnicity					
	Non-Hispanic White	**Black**	**Hispanic**	**Asian**	**Other**	**Total**
Waitlist candidates	19 418	2587	4193	1222	415	27 835
Total transplanted	8042	1192	1525	446	164	11 369
ABO-identical transplantation, % transplanted	7515 (93)	1078 (90)	1420 (93)	395 (89)	148 (90)	10 556 (93)
ABO-nonidentical transplantation, % transplanted	527 (7)	114 (10)	105 (7)	51 (11)	16 (10)	813 (7)
O → B, % ABO non-id txp	41	59	38	51	56	44
A → O, % ABO non-id txp	16	12	33	3	13	17
B → AB, % ABO non-id txp	17	12	7	16	13	15
A → AB, % ABO non-id txp	13	12	8	18	6	12
O → A, % ABO non-id txp	11	4	12	6	6	10
Other combinations, % ABO non-id txp	2	0	2	4	6	2

Data are shown as median (interquartile range) or as percentage.

TABLE 4

Univariable competing risks assessment of ABO-nonidentical transplantation

	Univariable Analysis	
	Subhazard ratio (95% CI)	***P*-value**
Age, year	0.98 (0.97–0.98)	<.001
Female	1.06 (0.92–1.23)	.41
Race/ethnicity		
Non-Hispanic White	Ref	Ref
Black	1.61 (1.32–1.98)	<.001
Hispanic	0.91 (0.74–1.13)	.40
Asian	1.54 (1.15–2.05)	.003
Other	1.40 (0.86–2.31)	.18
Recipient ABO status		
O	Ref	Ref
A	0.67 (0.51–0.87)	.004
B	9.47 (7.82–11.5)	<.001
AB	22.1 (18.0–27.2)	<.001
Etiology of liver disease		
Chronic hepatitis C	Ref	Ref
Alcohol	1.28 (1.05–1.55)	.013
Nonalcoholic fatty liver disease	0.96 (0.76–1.21)	.75
Autoimmune/cholestatic	1.34 (1.06–1.70)	.016
Chronic hepatitis B	1.52 (1.04–2.22)	.030
Other	1.48 (1.22–1.80)	<.001
Exception points		
Hepatocellular carcinoma	0.40 (0.32–0.50)	<.001
Other	0.69 (0.55–0.86)	.001
Laboratory MELD at listing	1.03 (1.03–1.04)	<.001
Listing center volume		
Low (#txp<38 during study period)	Ref	Ref
Medium (#txp>38 and<94)	1.02 (0.77–1.35)	.89
High (#txp>94)	1.01 (0.77–1.32)	.95
Region		
Low MELD (median<28 at txp)	Ref	Ref
Medium MELD (median 28–30)	1.13 (0.93–1.37)	.21
High MELD (median 30)	0.89 (0.76–1.03)	.12

MELD, Model for End-Stage Liver Disease.

TABLE 5

Multivariable models of the association between race/ethnicity and ABO-nonidentical transplantation

			Multivariable models[a]					
	Univariable analysis		Model 1		Model 2		Model 3	
	sHR (95% CI)	*P*-value	sHR(95%CI)	*P*-value	sHR(95%CI)	*P*-value	sHR(95%CI)	*P*-value
Race/ethnicity								
Non-Hispanic White	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Black	1.61 (1.32–1.98)	<.001	1.30 (1.06–1.62)	.013	1.30 (1.05–1.61)	.016	0.82 (0.65–1.01)	.067
Hispanic	0.91 (0.74–1.13)	.40	0.85 (0.68–1.04)	.12	0.90 (0.73–1.12)	.35	1.05 (0.84–1.31)	.67
Asian	1.54 (1.15–2.05)	.003	1.63 (1.18–2.25)	.003	1.70 (1.22–2.36)	.001	0.72 (0.51–1.03)	.074
Other	1.40 (0.86–2.31)	.18	1.28 (0.77–2.12)	.34	1.31 (0.79–2.17)	.30	1.37 (0.80–2.32)	.25
Region								
Low MELD (<28)					Ref	Ref	Ref	Ref
Medium MELD (28–30)					1.07 (0.88–1.30)	.51	0.88 (0.72–1.08)	.23
High MELD (>30)					0.83 (0.71–0.98)	.025	0.72 (0.61–0.85)	<.001
Recipient ABO Status								
O							Ref	Ref
A							0.68 (0.52–0.90)	.007
B							11.6 (9.43–14.1)	<.001
AB							29.3 (23.5–36.5)	<.001

N=27 324 in each model.

[a]Each model is also adjusted for recipient age, sex, etiology of liver disease, exception points granted, initial laboratory Model for End-Stage Liver Disease (MELD) score, and listing center volume.