

Racial and Ethnic Disparities in Access to Liver Transplantation

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Access to liver transplantation is reportedly inequitable for racial/ethnic minorities, but inadequate adjustments for geography and disease progression preclude any meaningful conclusions. We aimed to evaluate the association between candidate race/ethnicity and liver transplant rates after thorough adjustments for these factors and to determine how uniform racial/ethnic disparities were across Model for End-Stage Liver Disease (MELD) scores. Chronic end-stage liver disease candidates initially wait-listed between February 28, 2002 and February 27, 2007 were identified from Scientific Registry for Transplant Recipients data. The primary outcome was deceased donor liver transplantation (DDLT); the primary exposure covariate was race/ethnicity (white, African American, Hispanic, Asian, and other). Cox regression was used to estimate the covariate-adjusted DDLT rates by race/ethnicity, which were stratified by the donation service area and MELD score. With averaging across all MELD scores, African Americans, Asians, and others had similar adjusted DDLT rates in comparison with whites. However, Hispanics had an 8% lower DDLT rate versus whites [hazard ratio (HR) = 0.92, $P = 0.011$]. The disparity among Hispanics was concentrated among patients with MELD scores < 20, with HR = 0.84 ($P = 0.021$) for MELD scores of 6 to 14 and HR = 0.85 ($P = 0.009$) for MELD scores of 15 to 19. Asians with MELD scores < 15 had a 24% higher DDLT rate with respect to whites (HR = 1.24, $P = 0.024$). However, Asians with MELD scores of 30 to 40 had a 46% lower DDLT rate (HR = 0.54, $P = 0.004$). In conclusion, although African Americans did not have significantly different DDLT rates in comparison with similar white candidates, race/ethnicity-based disparities were prominent among subgroups of Hispanic and Asian candidates. By precluding the survival benefit of liver transplantation, this inequity may lead to excess mortality for minority candidates. *Liver Transpl* 16:1033-1040, 2010. © 2010 AASLD.

Received January 31, 2010; accepted May 12, 2010.

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The US Census Bureau projects that the US population will undergo rapid racial and ethnic diversification over the next 50 years. Minority populations are expected to grow by 2% per year over the next 3 decades in the United States. The African American population is expected to grow to encompass 15% of the US population, whereas Asian and Pacific Islanders will make up approximately 9%. Although Hispanics, making up 15% of the US population,

are currently the single largest ethnic minority group, they are projected to account for nearly a quarter of the population by 2050 (130 million in all).¹ Recent data also suggest that the incidence of chronic liver disease and hepatocellular carcinoma (HCC) is growing fastest in minority populations, particularly among Hispanics.²⁻⁸ The rapid diversification of the US population, coupled with the growing burden of liver disease in minority communities, suggests that the liver transplant waiting list of the future will have greater racial, ethnic, and cultural pluralism than it does currently.

Abbreviations: DDLT, deceased donor liver transplantation; DSA, donation service area; HCC, hepatocellular carcinoma; HR, hazard ratio; HRSA, Health Resources and Services Administration; MELD, Model for End-Stage Liver Disease; OPTN, Organ Procurement and Transplant Network; SD, standard deviation; SRTR, Scientific Registry of Transplant Recipients.

This study was presented in part at the plenary session of the American Transplant Congress, Boston, MA, June 3, 2009.

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DOI 10.1002/lt.22108

View this article online at wileyonlinelibrary.com.

LIVER TRANSPLANTATION.DOI 10.1002/lt. Published on behalf of the American Association for the Study of Liver Diseases

The need for racial/ethnic equity in liver transplantation among patients with the same medical urgency is necessary, but previous studies in this area have been narrow in their conception of race, have been potentially biased, or have been derived from cohorts of candidates who were wait-listed under obsolete allocation rules. African Americans reportedly had significantly lower transplant rates in the era prior to the adoption of the Model for End-Stage Liver Disease (MELD)-based liver allocation system,^{9,10} with improvement in the disparity supposedly occurring in the MELD era.^{3,10} These studies have failed to provide a complete evaluation of other minority groups, such as Hispanics and Asians, who account for a growing proportion of the waiting list.¹¹ Furthermore, previous disparity-related studies have not correctly adjusted for geographic factors that may affect the receipt of a liver transplant. The variation in the likelihood of receiving a liver transplant in different parts of the country has been well documented¹²⁻¹⁴ and is tied to the local availability of organs from deceased donors, the performance of organ procurement organizations, and transplant program practices.^{15,16} In order to better understand and address racial/ethnic disparities in liver transplantation in a policy framework, studies on racial/ethnic equity in liver transplantation must provide a more precise estimate of the scope of the problem by accounting for potential confounding factors.

Because of the growing racial/ethnic diversity of the liver waiting list, the intent of our study was to comprehensively characterize racial/ethnic disparities in access to liver transplantation in the context of the liver allocation system. Using data from the Scientific Registry of Transplant Recipients (SRTR), we aimed to evaluate any potential racial/ethnic inequity in wait-list event rates by accounting for patient differences, changes in disease over time, and geographic factors, all of which affect transplant rates.¹⁷ We also aimed to determine to what extent different levels of geographic adjustment [the local donation service area (DSA) level, the Organ Procurement and Transplant Network (OPTN) regional level, and groups of OPTN regions] affect measured differences in adjusted liver transplant rates between racial/ethnic groups. The liver allocation system is driven by the principle of medical urgency and theoretically is able to achieve equity in access to transplantation by remaining true to objective characterizations of liver disease severity.¹⁸ Using a carefully designed statistical approach that modeled access to liver transplantation based on the rules of liver allocation, we intended to identify any racial/ethnic disparities that were byproducts of the design of the allocation system.

PATIENTS AND METHODS

Data were obtained from the SRTR and were based on patient-level data submitted by transplant centers to the OPTN. After the exclusion of patients with acute liver failure (status 1), those under the age of 18 years, and those with previous liver transplants, the study population ($n = 39,114$) consisted of adult

chronic end-stage liver disease candidates initially added to the waiting list between February 28, 2002 and February 27, 2007. The start date corresponded to the initiation date of MELD-based liver allocation by the OPTN, whereas the end date was chosen so that up to 5 years of follow-up data were available.

In our analysis, race and ethnicity were considered jointly. Both race and ethnicity represent a social context that frames personal and cultural identity, attitudes toward health, health practices, and behavioral risks that may precipitate disease. These constructions may also shape patient interactions with the health care system by affecting the expectations and perceptions of both the patients and the providers in health care encounters.¹⁹ We used race and ethnicity definitions provided by transplant centers with the OPTN data collection infrastructure. Race and ethnicity were defined as non-Hispanic white (white), African American, Hispanic, Asian, or other, with the last including Native Americans, Native Alaskans, Native Hawaiians, and those of undefined or mixed race/ethnicity (eg, black Hispanics). Our principal aim was to determine whether deceased donor liver transplantation (DDLT) rates differed by candidate race/ethnicity.

Cox regression was used to compare race/ethnicity-specific rates of DDLT among active patients.²⁰ Follow-up began for patients when they were initially added to the waiting list. They were followed until the earliest of liver transplantation, death, the granting of a MELD exception score, or the end of the observation period (February 27, 2007). In order to assess the workings of the allocation system, we modeled the rate of DDLT among active patients because donor livers cannot be allocated to those who are inactivated, are removed from the waiting list, or die on the waiting list.²¹ Correspondingly, follow-up data for patients who were removed from the waiting list or were inactive for any period of time (eg, for temporary illnesses or other issues that precluded liver transplantation) were excluded. Observation of a patient was subsequently reinitiated if and when the patient was reactivated. Patients were censored from the analysis at the time at which they received a living donor liver transplant or a MELD exception score (eg, for HCC), if this was applicable. Differences in access to liver transplantation were represented by hazard ratios (HRs) and were expressed as percentage changes in relative rates.

The Cox models were stratified by the integer MELD score and included several covariates from the SRTR candidate file; this included age, gender, diagnosis, diabetes, body mass index, hospitalization status at listing, receipt of dialysis, albumin, and prior malignancy. The MELD score, albumin level, and use of dialysis were time-dependent covariates, and this meant that all of a candidate's changes with respect to such factors recorded in data submitted to the OPTN were incorporated into the analysis. In all, 98 patients had at least 1 missing data element in the baseline adjustment covariates, and these patients were excluded.

In order to study the effect of geography on measured differences in transplant rates between minority

groups and whites, we created 3 separate geographic adjustment models. A previous study, using a model adjusted for geography with consolidated OPTN regions, identified African Americans as having significantly decreased transplant rates with respect to whites.¹⁰ We created 2 additional models, one adjusted for each individual OPTN region and another adjusted for the DSA, the primary level of organ distribution. By comparing these 3 models, we could identify how transplant rates differed between minority groups and whites registered in the same geographic unit. Subsequent comparisons of racial/ethnic differences in adjusted DDLT rates were obtained with models stratified by the DSA in addition to the MELD score.

Further analysis was directed toward evaluating whether the association between race/ethnicity and liver transplant rates was modified by medical urgency or geography (ie, interactions). First, to determine if the impact of race/ethnicity differed by medical urgency, we fitted models that estimated separate MELD category-specific race/ethnicity effects. This involved fitting models with product terms defined by indicators for the race/ethnicity group and MELD category. MELD categories were based on a modification of the ranges based on liver transplant survival benefit.²² These categories were MELD ranges of 6 to 14, 15 to 19, 20 to 29, and 30 to 40, and they were derived by the grouping of candidates with adjacent MELD scores to ensure an adequate number of transplant events in each group. Second, we fitted models that enabled direct comparisons of relative transplant rates between racial/ethnic minorities and whites registered in the same DSAs within each OPTN region. We also fitted additional models to determine whether race/ethnicity affected the transitions from active wait-list status to inactivation, removal, and death, which were stratified by the integer MELD score and DSA. These models were censored at transplantation and the granting of a MELD exception. Models to determine the effect of race/ethnicity and MELD interactions on these other outcomes were also fitted.

This study was approved by the US Health Resources and Services Administration (HRSA) SRTR project officer. HRSA determined that this study satisfied the criteria for the institutional review board exemption described in the Public Benefit and Service Program provisions of 45 CFR 46.101(b)(5) and HRSA Circular 03. All statistical analysis was performed with SAS version 9.2 (SAS Institute, Cary, NC). Statistical significance was defined as $P < 0.05$.

RESULTS

Clinical characteristics of the 39,114 patients in the study population are displayed in Table 1. Whites made up 74.1% of wait-listed patients, Hispanics made up 13.9%, African Americans made up 7.3%, Asians made up 3.7%, and others made up less than 1%. Racial/ethnic subgroups were significantly different with respect to the following factors: age at wait-listing, sex, diagnosis, MELD score at listing, body

mass index, and percentage of patients on dialysis, with $P < 0.0001$ in each case. The mean age at wait-list registration ranged from 49.5 (African Americans) to 53.6 years (Asians). The proportion of male candidates was lowest in the Other group (57.8% male) and highest in the Asian population (68.2% male). With respect to diagnosis, African Americans also had the highest proportion of hepatitis C candidates. African Americans had the highest proportion of patients with cholestatic liver disease, and Asian and other candidates had the highest proportions of patients with noncholestatic liver disease. Hepatitis B was not the sole cause of liver failure for any individual racial/ethnic group, and this was congruent with previously reported national data.²³ The median MELD score at listing was at least 2 points higher for African Americans versus whites, Hispanics, or Asians. At transplant, African Americans and Hispanics had the highest median MELD scores. Hispanics had a significantly higher proportion of blood type O candidates. Whites had the highest proportion of blood type A candidates. Asians had the highest proportions of blood type B and AB candidates. With respect to comorbidities, African Americans had the highest proportion of dialysis-dependent candidates; 8.1% to 10.3% of the candidates had diabetes, and there were significantly more diabetics among Hispanics versus the other groups. The mean body mass index was lowest among Asian candidates and highest among Hispanic candidates. Of all groups, African Americans had the highest proportion of candidates on dialysis at registration.

The geographic variation in measured disparities in liver transplant rates between minorities and whites is represented in Fig. 1. Each bar represents the difference in adjusted liver transplant rates between African Americans and whites for a defined unit of geographic comparison. When relative transplant rates were compared between African Americans and whites registered in the same quadrant of the country (grouped contiguous OPTN regions: northeast, southeast, northwest, and southwest), in agreement with the geography adjustment by Moylan et al.,¹⁰ African Americans had a significantly lower adjusted transplant rate (by 10%) versus whites, with a covariate-adjusted HR of 0.90 ($P = 0.0001$). Similarly, when African Americans and whites registered in the same OPTN region were compared, the relative transplant rate was also significantly lower for African Americans (HR = 0.87, $P = 0.0001$). However, when African Americans and whites registered in the same DSA were compared, the disparity between African Americans and whites was minimal and not statistically significant (HR = 0.98, $P = 0.50$).

Figure 2 displays the risk-adjusted differences in relative liver transplant rates for African Americans, Hispanics, Asians, and those of other race/ethnicity versus whites. The nonsignificant 2% lower rate for African Americans (adjusted for the DSA) is as described in Fig. 1. In contrast to African Americans, Hispanics had a significantly lower liver transplant

TABLE 1. Clinical Characteristics of Wait-Listed Liver Transplant Candidates in the Study Cohort by Race/Ethnicity in the MELD Era (n = 39,114)

Variable	White (n = 28,989)	African American (n = 2865)	Hispanic (n = 5452)	Asian (n = 1450)	Other (n = 358)	P Value
Age at wait-list registration, years [mean (SD)]	52.6 (9.3)	49.5 (10.5)	52.0 (9.5)	53.6 (10.5)	50.5 (9.5)	<0.0001
Sex [n (%)]						<0.0001
Male	19,203 (66.2)	1702 (59.4)	3341 (61.3)	989 (68.2)	207 (57.8)	
Female	9786 (33.8)	1163 (40.6)	2111 (38.7)	461 (31.8)	151 (42.2)	
Diagnosis [n (%)]						<0.0001
Cholestatic	2850 (9.8)	314 (11.0)	299 (5.5)	62 (4.3)	29 (8.1)	
Noncholestatic	10,311 (35.6)	674 (23.5)	1944 (35.7)	638 (44.0)	145 (45.5)	
Hepatitis C	11,511 (39.7)	1405 (49.0)	2566 (47.1)	378 (26.1)	122 (34.1)	
Acute hepatic necrosis	429 (1.5)	74 (2.6)	98 (1.8)	83 (5.7)	13 (3.6)	
Malignant neoplasm (non-HCC)	650 (2.2)	65 (2.3)	141 (2.6)	99 (6.8)	18 (5.0)	
Metabolic disease	630 (2.2)	18 (0.6)	41 (0.8)	13 (0.9)	5 (1.4)	
Other	2608 (9.0)	315 (11.0)	363 (6.7)	177 (12.2)	26 (7.3)	
Blood type [n (%)]						<0.0001
A	11,857 (40.9)	786 (27.4)	1673 (30.7)	362 (25.0)	122 (34.0)	
B	3130 (10.8)	589 (20.6)	551 (10.1)	383 (26.4)	37 (10.3)	
O	12,901 (44.5)	1371 (47.9)	3102 (56.9)	582 (40.1)	189 (52.7)	
AB	1098 (3.8)	119 (4.2)	126 (2.3)	123 (8.5)	11 (3.1)	
Body mass index, kg/m ² [mean (SD)]	28.6 (5.8)	28.2 (6.0)	28.9 (5.7)	24.6 (4.3)	29.4 (6.1)	<0.0001
Renal failure, dialysis [n (%)]	817 (2.8)	173 (6.0)	225 (4.1)	56 (3.9)	16 (4.5)	<0.0001
Diabetes [n (%)]	2551 (8.8)	264 (9.2)	561 (10.3)	117 (8.1)	37 (10.3)	0.0050
Coronary artery disease [n (%)]	460 (1.6)	36 (1.3)	60 (1.1)	10 (0.7)	5 (1.4)	0.0007
Chronic obstructive pulmonary disease [n (%)]	492 (1.7)	30 (1.1)	47 (0.9)	8 (0.6)	6 (1.7)	<0.0001
MELD score at listing [median (25th, 75th percentiles)]	14 (11, 19)	17 (12, 23)	15 (11, 20)	13 (9, 19)	16 (12, 22)	
MELD score at transplant [median (25th, 75th percentiles)]	18 (13, 24)	20 (13, 26)	20 (12, 27)	14 (7, 21)	19 (14, 24)	

NOTE: Percentages are column percentages.

rate (by 8%) versus whites (HR = 0.92, $P = 0.011$). Candidates who were Asian or of other race/ethnicity had no significant differences in liver transplant rates versus whites. Interaction tests between race/ethnicity, sex, and diagnosis were not significant.

In order to sharpen our understanding of which subsets of minority candidates were affected by the disparity, we determined differences in transplant rates within each MELD stratum (Fig. 3). There were no significant differences in liver transplant rates between African Americans and whites at any MELD scores. Asian candidates with lower MELD scores had a 24% higher transplant rate with respect to whites with the same scores (HR = 1.24, $P = 0.024$), but the sickest Asian patients had nearly half the transplant rate of their white counterparts (HR = 0.54, $P = 0.004$). Hispanic candidates who were registered in the same DSA displayed 15% to 16% lower transplant rates in comparison with whites when they had MELD scores less than 20, with HR = 0.84 ($P = 0.021$) for MELD scores of 6 to 14 and HR = 0.85 ($P = 0.009$) for MELD scores of 15 to 19. With MELD scores above 20, Hispanics and whites did not have significantly different transplant rates within the same DSA.

Racial/ethnic differences were noted in other wait-list events as well. Compared with whites, African Americans had significantly lower wait-list removal rates for reasons other than transplantation (HR = 0.93, $P = 0.004$). Similarly, Asians also had significantly lower nontransplant removal rates (HR = 0.89, $P = 0.009$). Hispanics trended toward a lower removal rate in comparison with whites, but this was not statistically significant (HR = 0.96, $P = 0.073$). With respect to racial/ethnic differences in wait-list mortality, African Americans, while active on the wait list, had a 37% lower mortality rate than whites (HR = 0.63, $P < 0.0001$). Asians maintained a 27% lower mortality rate versus whites (HR = 0.73, $P = 0.007$). Hispanics did not have a significantly different death rate in comparison with whites. There were no significant differences in wait-list inactivation rates by race/ethnicity.

DSA-adjusted transplant rates for African Americans, Hispanics, and Asians varied extensively across OPTN regions (Fig. 4). However, after covariate adjustments, 7 of 11 OPTN regions displayed no significant differences in transplant rates when the respective minority groups were compared with whites. No single

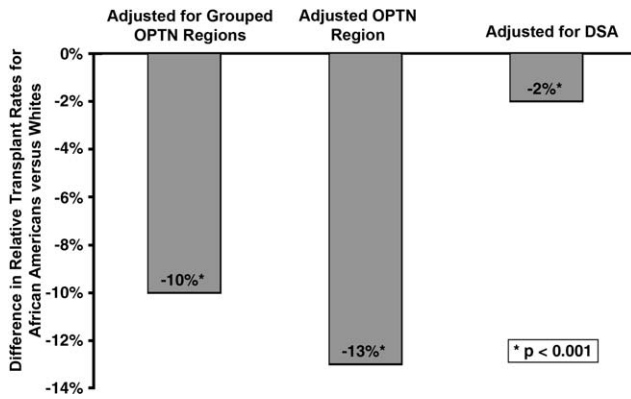


Figure 1. The apparent deficit in liver transplant access for African Americans is confounded by geography in the MELD era. This figure demonstrates the differences in relative transplant rates between African Americans and whites when they were compared with 3 different methods of geographic adjustment. When adjustments were made for geography by grouped adjacent OPTN regions (as described by Moylan et al.¹⁰) and even by individual OPTN regions, African Americans appeared to have a significantly lower liver transplant rate than whites in the same geographic areas. The DSA is the primary geographic unit of liver allocation in the United States. When African Americans and whites registered in the same DSA were compared, no significant difference in access to liver transplantation from the waiting list was noted.

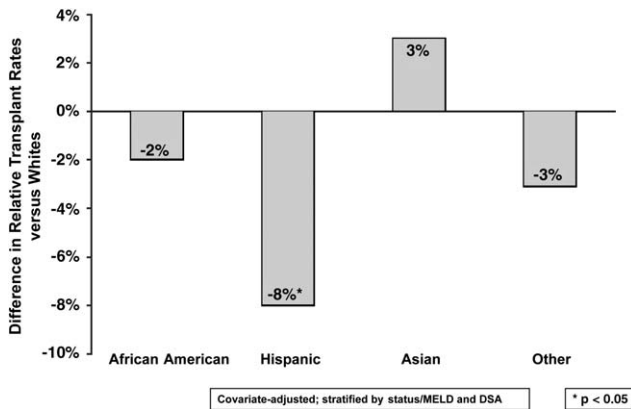


Figure 2. Racial/ethnic variation in relative liver transplant rates in the MELD era. According to the DSA level and other risk adjustments, the relative transplant rates for Hispanics were significantly lower than those for whites. African Americans had transplant rates similar to those of whites (see Fig. 1). There was a small trend toward a 3% higher transplant rate for Asians versus whites, but it was not significant. For other or mixed race candidates, there was a nonsignificant trend toward a 3% lower liver transplant rate versus whites. The models incorporated all changes in the MELD score reported to the SRTR.

region demonstrated significant disparities for all minority groups. African Americans did not have any statistically significant differences in transplant rates versus whites in any OPTN region. Region 2, which includes Pennsylvania, Maryland, New Jersey, Delaware, West Virginia, Washington, DC, and northern Virginia, demonstrated significantly lower transplant

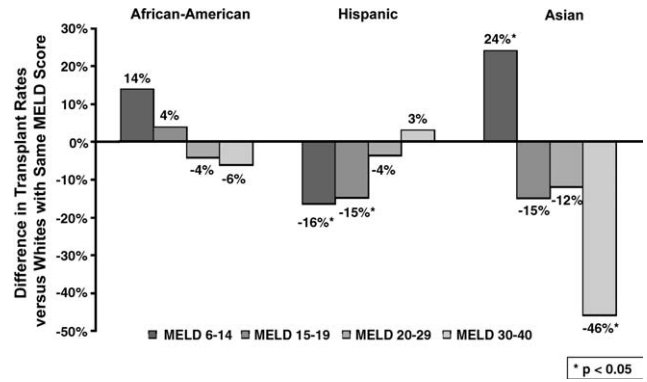


Figure 3. Relative liver transplant rates by race/ethnicity and MELD score. After further stratification of each racial group by the MELD score, several findings were prominent. African Americans did not have significantly different transplant rates versus whites at any MELD score. Hispanic candidates had significantly lower transplant rates (by 15%-16%) versus whites with similar disease severity with MELD scores less than 20. Asian candidates demonstrated 24% higher liver transplant rates with the lowest MELD scores but 46% lower transplant rates with the highest MELD scores. The analysis incorporated all changes in the MELD scores reported to the SRTR, and these transplant rate differences reflect the outcomes while candidates maintained a MELD score within a particular range.

rates for Hispanics versus whites (HR = 0.77, $P = 0.021$). The access of Asian candidates to liver transplantation varied widely. In region 3, which includes most of the southeastern United States, Asians demonstrated a 41% higher transplant rate versus whites (HR = 1.41, $P = 0.051$). Regions 9 and 10, which contain the DSAs that serve New York, western Vermont, Ohio, Indiana, and Michigan, demonstrated 36% to 60% lower transplant rates for Asian candidates, with HR = 0.63 ($P = 0.009$) for region 9 and HR = 0.40 ($P = 0.037$) for region 10.

DISCUSSION

Racial/ethnic disparities in transplantation have been framed as the culmination of a series of successive barriers in access to care that marginalize minorities with organ failure.^{2,17,24-26} Our findings demonstrate racial/ethnic variation in access to liver transplantation at a critical step: the transition from transplant candidate to transplant recipient. Racial/ethnic disparities at this step in the transplant process are important because liver transplant candidates are a highly selected population overcoming clinical and nonclinical barriers to get onto the waiting list.¹⁷ The clinical outcome of these candidates is based on individual disease progression, the continued ability to access specialized hepatological care, and the efficacy of the liver allocation system. We observed significantly lower liver transplant rates for subgroups of minority candidates versus their white counterparts, particularly among Hispanic candidates and Asians with high MELD scores. Importantly, these lower

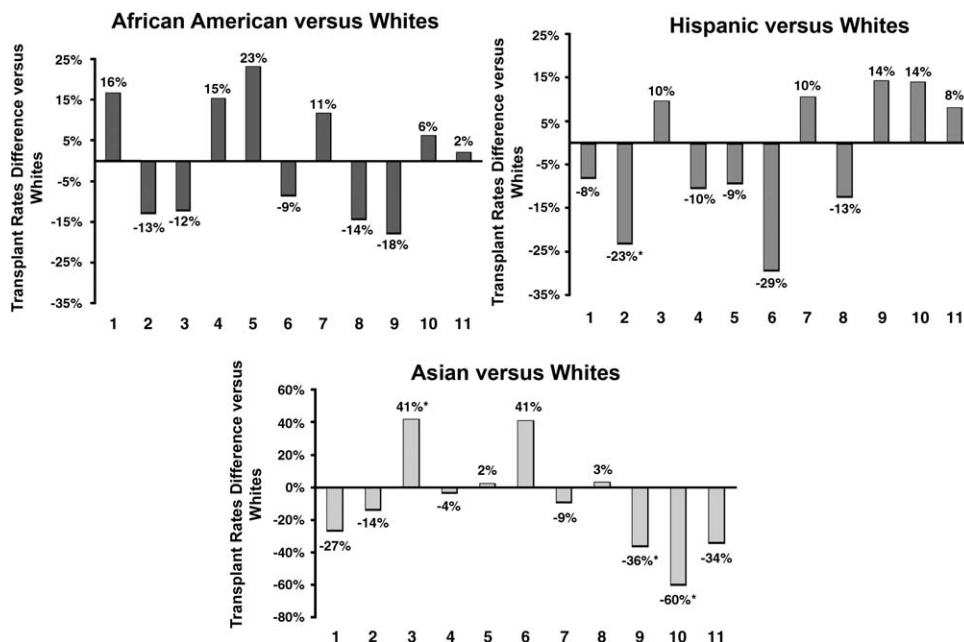


Figure 4. Regional variation in access to liver transplantation for minority candidates. Across all minority groups, the 11 OPTN regions covering the United States demonstrated an impressive degree of variation in relative transplant rates in comparison with white candidates. Four regions demonstrated significantly different transplant rates for a minority group versus whites. Five regions trended toward lower transplant rates for African Americans versus whites. Six regions demonstrated trends toward lower liver transplant rates for Hispanics, and the rates in region 2 reached statistical significance in this respect. For Asian candidates, 7 regions trended toward lower access to liver transplantation in comparison with whites. Regions 9 and 10 had much lower transplant rates for these candidates versus their respective white counterparts, but region 3 had significantly higher transplant rates for Asians. The analysis incorporated all changes in the MELD scores reported to the SRTR. An asterisk indicates significance.

transplant rates were not accompanied by higher rates of alternate wait-list outcomes, including death, removal for nontransplant reasons, and inactivation. By showing geographic heterogeneity in racial/ethnic differences in access to transplant, we also demonstrated “a difference in differences” in liver transplant rates. To the best of our knowledge, our study is the first to broadly address disparities in access to liver transplantation across all racial/ethnic groups and to identify the importance of properly accounting for geographic variation.

Geographic variation is being increasingly recognized as a threat to optimizing the use of donated organs^{12,27} and in our study had a clear effect on the measured differences in transplant rates between minorities and whites. African Americans did not have different adjusted transplant rates versus whites when they were compared at the DSA level. Moylan and colleagues¹⁰ previously studied access to liver transplantation for African American and white candidates and also found no differences in transplant rates. By grouping OPTN regions together, they imprecisely adjusted for geography and suggested, for example, that candidates in Florida have access to transplantation similar to the access of candidates in Texas, even though organ availability is highly variable across DSAs. Furthermore, they did not evaluate ethnic minorities other than African Americans and did not account for changes in the

severity of liver disease over time while candidates were wait-listed. It was therefore appropriate to evaluate racial/ethnic disparity in access to transplantation at the DSA level to improve precision in our estimates. Our findings suggest that the locale in which candidates seek care for their liver disease modifies the effect of race/ethnicity on access to liver transplantation.

Volk and colleagues¹⁶ assessed disparities in access to liver transplantation and suggested that differences in the median waiting time between DSAs, a proxy for organ availability, mediated racial/ethnic inequity. Our analyses differ from their work in several important ways. In contrast to Volk et al., who focused on African Americans and Hispanics, we evaluated disparities across all racial/ethnic groups, including whites, African Americans, Hispanics, Asians, and those of mixed or other ethnic heritage. We specifically focused on the identification of residual disparities within MELD subgroups and geographic areas. Methodologically, this focus was manifested in our measurement of racial/ethnic differences in transplant rates during active wait-list time and in our exhaustive treatment of the intersection of race/ethnicity, MELD score, and geography. In addition, we gave due consideration to competing risks, including inactivation, removal for reasons other than transplant, and death. Volk et al. considered any difference in transplant rates after registration to be a disparity.

However, because of the dynamic nature of the liver transplant wait list, their failure to identify a disparity in access among Hispanics was predicated, in the absence of analysis, on there being no racial/ethnic differences in rates of inactivation, reactivation, removal for reasons other than transplant, and granting of MELD exception scores. Our approach addressed these realities for African American, Hispanic, and Asian candidates in the context of allocation rules that are intended to apply to all candidates and also accounted for the extent to which geography modified the effect of race and ethnicity.

An important finding in this study was the lack of an overall disparity in transplant rates between African Americans and whites. This was also true across MELD scores and OPTN regions. This contrasts with a pre-MELD era study by Reid et al.,⁹ who reported significant disparities in access to transplantation for African Americans. African Americans did present with more advanced disease at registration in comparison with whites in our study, but the equitable transplant rate observed after we accounted for this advanced disease is the intended result of a medical urgency-based organ allocation system. However, registration on the wait list with more advanced disease signifies an important and persistent issue in the continuum of care of patients with liver disease, as suggested by Moylan et al.¹⁰ The delay in wait-list registration likely symbolizes impaired access to quality pretransplant care and may indicate that African Americans suffer from greater disease-related morbidity before registration.^{2,17,28,29} Further study on the timeliness and appropriateness of physician referral of African Americans with chronic liver disease to transplant centers is clearly a necessity.

The disparities noted in this analysis must be considered in the context of whether patients receive a survival benefit with a liver transplant. Once a patient reaches a MELD score of 12 or higher, the survival benefit of receiving a liver transplant is realized.³⁰ Hispanics with MELD scores of 6 to 14 had a 16% lower transplant rate and those with MELD scores of 15 to 20 had a 15% lower transplant rate versus whites with the same MELD scores. Asians with MELD scores of 6 to 14 had a 24% higher transplant rate, whereas those with highest MELD scores had a 46% lower transplant rate in comparison with whites with the same MELD scores. Minority candidates who have lower transplant rates at the lowest MELD scores arguably do not suffer from a disparity because these patients with well-compensated disease are unintentionally spared the risk of a liver transplant. Conversely, Asians are potentially harmed by a higher transplant rate at low MELD scores.²² The lower transplant rate at high MELD scores also disadvantages Asians because liver transplantation provides, at this end of the MELD spectrum, the most survival benefit. In aggregate, our data indicate which subgroups of minority candidates truly have impaired access to liver transplantation.

Another contribution of this analysis is the demonstration of variation in relative transplant rates for members of individual racial/ethnic groups by geography. Region 2

had a significantly lower transplant rate for Hispanic candidates compared with whites, with notable trends toward lower access in five other OPTN regions. Transplant rates for Asian candidates varied tremendously across the country, with 3 regions showing significantly different access for those candidates in comparison with whites. Region 3 demonstrated a more than 40% higher rate of transplantation for Asians, and regions 9 and 10 had significantly lower transplant rates for Asians versus whites. Additionally, 5 other regions trended toward lower transplant rates for Asians. Although African Americans trended toward lower transplant rates in 5 regions, there was no statistically significant difference in adjusted transplant rates between African Americans and whites in any region. The geographic analysis has some limitations with respect to statistical power, but identification of the geographic areas that have marginal access for a particular racial/ethnic group may help providers gain insight into practice patterns that may be responsible for these observations. This variation may be tied to differences in clinical decision making by transplant surgeons that may be driven by the candidate's clinical condition as well as the local and regional realities of organ availability. Furthermore, providers may manage their waiting lists differently according to their specific candidates, the proximity of other liver transplant programs, organ acceptance patterns, and many other factors. Geographic variation may modify racial/ethnic effects via the providers themselves. Some areas may have more diversity among transplant providers and may provide patients the opportunity for more racially/ethnically concordant patient-physician interactions, which may ultimately decrease undesirable wait-list outcomes for minority candidates.

Our study has some limitations. Although our study cohort is the largest to date concerning racial/ethnic disparities in liver transplant rates, our statistical models are limited by the covariates in the SRTR data. We have previously recommended the collection of more granular data, specifically with respect to measuring disparities in transplantation.¹⁷ Patients were also censored when they received a MELD exception for HCC; this is growing in incidence among minorities and accounts for 15% to 20% of the US liver transplant volume.^{11,31} Our focus was to identify disparities through the use of a clinically homogeneous population, and MELD exceptions artificially boost access to liver transplantation. Differential access to these exceptions, depending on variations in pathophysiology, geographic differences in the granting of MELD exceptions, and variations in the use of adjuvant therapies, might have biased our understanding of disparities if we had continued our observation of patients beyond the granting of MELD exceptions. Finally, these data represent summative population-based estimates and are not immediately usable by individual patients trying to determine their chances of receiving a liver transplant versus others or deciding where they should pursue liver transplant candidacy. The effect of race or ethnicity on transplant rates cannot be ascribed to individual patients in that group.

Previous authors have noted that, although this is not specifically prescribed by the Final Rule, allocation based on medical urgency should have the beneficent effect of racial/ethnic equity.³² Most transplant physicians, surgeons, and policy makers would agree that the current liver allocation system is fairer than that of a decade ago, but as we have demonstrated, it is not yet equitable. Our work demonstrates that members of rapidly growing segments of the population developing liver disease have impaired access to a lifesaving treatment. Balancing values in the allocation of scarce medical resources is unique to transplantation and will continue to challenge the transplant community until the organ supply meets the demand. Although providing members of certain racial/ethnic groups with an advantage in allocation in order to improve equity seems unethical, the public and the transplant community have a responsibility to thoroughly evaluate allocation policy changes for the potential to precipitate or exacerbate unintended disparities. If we remain vigilant and cognizant of these important issues in the development of transplant policy and in research on disparities, equity and sensible liver transplant allocation policy do not need to be mutually exclusive.

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