Rates of Solid-Organ Wait-listing, Transplantation, and Survival Among Residents of Rural and Urban Areas

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For patients with end-stage heart, liver, and kidney disease, organ transplantation offers the best and often only hope for long-term survival. However, despite federal regulation and national efforts to ensure equal access to the limited pool of donated organs, previous research has demonstrated the presence of significant barriers to access to transplantation services for racial minorities, women, and patients with low socioeconomic status or inadequate insurance. The factors contributing to the disparity in access to renal transplantation include perceived differences in patient preferences, differential rates and timing of referrals, variation in the rates and timeliness of the completion of transplant evaluations, and organ allocation policies favoring highly matched donors and recipients.

Nearly 14% of the US population lives outside of major urban areas. Patients who live in rural regions and small towns face multiple barriers to health care access, including the need to travel long distances, the lack of locally available specialty services, and difficulty in receiving follow-up care.

Context Disparities in access to organ transplantation exist for racial minorities, women, and patients with lower socioeconomic status or inadequate insurance. Rural residents represent another group that may have impaired access to transplant services.

Objective To assess the association of rural residence with waiting list registration for heart, liver, and kidney transplant and rates of transplantation among wait-listed candidates.

Design, Setting, and Patients Five-year US cohort of 174,630 patients who were wait-listed and who underwent heart, liver, or kidney transplantation between 1999 and 2004.

Main Outcome Measures Rates of new waiting list registrations and transplants per million population for residents of 3 residential classifications (rural/small town population, <10,000; micropolitan, 10,000-50,000; and metropolitan >50,000 or suburb of major city).

Results Compared with urban residents, waiting list registration rates for rural/small town residents were significantly lower for heart (covariate-adjusted rate ratio [RR]=0.91; 95% confidence interval [CI], 0.86-0.96; P<.002), liver (RR=0.86; 95% CI, 0.83-0.89; P<.001), and kidney transplants (RR=0.92; 95% CI, 0.90-0.95; P<.001). Compared with residents in urban areas, rural/small town residents had lower relative transplant rates for heart (RR=0.88; 95% CI, 0.81-0.94; P=.004), liver (RR=0.80; 95% CI, 0.77-0.84; P<.001), and kidney transplantation (covariate-adjusted RR=0.90; 95% CI, 0.88-0.93; P<.001). These disparities were consistent across national organ allocation regions. Significantly longer waiting times among rural patients wait-listed for heart transplantation were observed but not for liver and kidney transplantation. There were no significant differences in posttransplantation outcomes between groups.

Conclusions Patients living in rural areas had a lower rate of wait-listing and transplant of solid organs, but did not experience significantly different outcomes following transplant. Differences in rates of wait-listing and transplant may be due to variations in the burden of disease between different patient groups or barriers to evaluation and waiting list entry for rural residents with organ failure.

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transplant centers are predominantly clustered in large urban centers. For these patients, lack of access may result in premature or avoidable death.

The impact of rural residence on waiting list access and transplant rates has been poorly characterized. The purpose of this investigation was to evaluate population-based rates of entry onto waiting lists and transplantation for patients in urban and rural regions, to assess the impact of rural residence on access to transplant services for this population.

METHODS

Data Sources

National data on all patients wait-listed for transplant and undergoing transplant are collected by the Organ Procurement and Transplantation Network (OPTN) and analyzed by the Scientific Registry of Transplant Recipients under a contract administered by the Health Resources and Services Administration, US Department of Health and Human Services. A 5-year cohort of data from the Scientific Registry of Transplant Recipients, including all patients who were wait-listed or underwent heart, liver, or kidney transplantation in the United States between July 1999 and June 2004, was examined for this study.

Donor and recipient data included clinical, outcome, and demographic information, which included self-classified race and ethnicity of participants. Race and ethnicity were assessed because of the established association with the prevalence of end-stage organ disease within the population. This study was approved by the project officer for the Scientific Registry of Transplant Recipients, Health Resources and Services Administration, who determined that it satisfies the criteria for institutional review board exemption.13,14

Analysis

Patient and Geographic Classification. Patients were classified by zip code of residence at the time of listing or transplant using the rural-urban commuting area (RUCA) code.13 A RUCA code is assigned to each US zip code based on factors that include standard US Census urbanized place definitions (based on population density) and supplemental employment commuting data, to assess the functional relationship between population centers and the surrounding communities. Thus, suburban areas with low population density but close employment associations with large urban centers are classified as urban. The RUCA taxonomy includes codes from 1.0 (most urban) to 10.6 (most rural). For this analysis, 3 independent RUCA groups were defined prior to data analysis: metropolitan (RUCA 1.0-3.9), which includes cities with a population of more than 50,000 and the associated suburban areas; micropolitan (RUCA 4.0-6.0) for smaller cities or towns of 10,000 to 50,000; and rural or small town (RUCA 7.0-10.6), for populations of less than 10,000 (TABLE 1). These groupings reflect centers with similar population characteristics and population density. The RUCA taxonomy has been applied in other areas of health services research to characterize the health status of populations that live outside of major urban centers.16

Additional analyses were conducted comparing metropolitan, micropolitan, and rural/small town areas in each region.

Rates of New Wait-List Entry and Transplantation. The incidence rates of new wait-listings for heart, liver, and kidney transplantation and the rates of transplantation for each type of transplant were examined using national OPTN data. Unadjusted rates were calculated as counts per million population over the 5-year period for each of the 3 RUCA groups for the entire United States and for each of the 11 OPTN regions by RUCA group. Unadjusted and covariate-adjusted rates for rural and urban regions were compared using Poisson regression, with zip codes as the unit of analysis. The fact that zip code populations differ in size was factored into the models through an offset term. Models for covariate-adjusted comparisons included the terms age, race, and sex (each expressed as zip code–level percentages), and median household income. Poisson regression was used because of its long history of use in cohort studies in which, as here, the events of interest are considered rare.17

Time to Transplantation Once Wait-Listed. A Cox proportional hazards model was constructed to evaluate the relative impact of demographic and clinical factors on the time to transplant among wait-listed patients. In this model, organ-specific transplant rates were modeled adjusting for important patient characteristics such as age, race, sex, diagnosis, and degree of sensitiz-
tion. A variable for the organ procurement organization of the listing transplant center was included in these analyses to control for disparities in average waiting times between OPTN regions.

**Patient and Graft Survival Following Transplantation.** Organ-specific Cox proportional hazards models were constructed that included both donor and recipient characteristics as independent variables to assess the independent impact of micropolitan and rural residence on patient (heart and liver) or graft (kidney) survival following transplantation. Analyses were facilitated using SAS version 9.1 (SAS Institute Inc, Cary, North Carolina). Statistical significance was defined by a P value of less than .05.

**RESULTS**

Nationally, 37.8 million individuals live in US small towns or isolated rural areas, comprising 14% of the overall US population (Table 1). The demographic characteristics of the rural and urban regions are generally similar, although racial minorities tend to comprise a greater proportion of urban region populations. The urban population is also more likely to have achieved a high school education or greater.

During this 5-year analysis, nearly 175,000 patients were wait-listed and 97,445 received a heart, liver, or kidney transplant. Isolated rural and small town patients comprised 14% of new heart transplant listings, 11% of new liver transplant listings, and 11% of new kidney transplant listings. Patients who resided in isolated rural regions or small towns received 13% of heart, 12% of liver, and 12% of kidney transplants.

**Rates of Wait-Listing**

The rates of new listings for organ transplant per million population over a 5-year interval was calculated by location of residence (Table 2). The unadjusted rates of new listings were significantly higher for urban residents compared with residents in small population centers for liver (180.4 vs 138.4; RR=0.77; P<.001) and kidney transplants (428.4 vs 326.7 listings/million population; RR=0.76; P<.001) (Table 2). After adjusting for demographic characteristics, the rates of new listings in rural regions were significantly lower for all 3 organs: heart (RR=0.91; P=.002), liver (RR=0.86; P<.001), and kidney (RR=0.92; P<.001). Corresponding adjusted wait-listing per million population in urban vs rural/small town regions were 50.6 vs 46.0 for heart, 173.2 vs 148.7 for liver, and 383.4 vs 354.7 for kidney transplantation (adjusted for median household income, sex, age, and race/ethnicity). Patients in micropolitan regions experienced wait-listing rates that were similarly lower than their urban counterparts.

**Rates of Transplantation**

The unadjusted rates of transplantation varied significantly according to location of residence (Table 3). When compared with urban areas, the rate of heart transplantation per million population over the 5-year cohort was lower in rural/small town regions at 33.0 vs 31.2 transplants, respectively (RR=0.94; P=.07). For residents of isolated rural regions and small towns, transplant rates were significantly lower for liver (79.2 vs 66.5; RR=0.84; P<.001), and kidney (247.4 vs 218.1; RR=0.88; P<.001). Similarly, lower transplant rates were found for residents of micropolitan regions (populations 10,000-50,000) compared with urban residents for liver transplants (79.2 vs 63.8; RR=0.81; P<.001) and kidney transplants (247.4 vs 214.4; RR=0.87; P<.001).

After adjustment, rural residents had a lower rate of heart transplant (RR=0.88; P=.004), liver transplant (RR=0.80; P<.001), and kidney transplant (RR=0.90; P<.001) when compared with urban residents. The corresponding adjusted transplant rates per million population for urban vs rural/small town regions were 33.1 vs 29.0 for heart, 81.4 vs 65.5 for liver, and 242.5 vs 219.2 for kidney.

The lower rates of transplantation were not confined to a specific OPTN region or a single area of the United States.

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**Table 2. Unadjusted and Adjusted Wait-Listing Rates for Heart, Liver, and Kidney Transplantation for 5-Year Cohort**

<table>
<thead>
<tr>
<th></th>
<th>Metropolitan (Urban)</th>
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<th>Micropolitan</th>
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<th>Rural/Small Town</th>
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<tr>
<td><strong>Unadjusted Waiting List Registration Rates</strong></td>
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<tr>
<td><strong>Listings per Million</strong></td>
<td>RR (95% CI)</td>
<td><strong>Listings per Million</strong></td>
<td>RR (95% CI)</td>
<td><strong>P Value</strong></td>
<td><strong>Listings per Million</strong></td>
<td>RR (95% CI)</td>
</tr>
<tr>
<td>Heart 50.1</td>
<td>1 [Reference]</td>
<td>48.1</td>
<td>0.96 (0.91-1.01)</td>
<td>.15</td>
<td>49.2</td>
<td>0.98 (0.93-1.03)</td>
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<tr>
<td>Liver 180.4</td>
<td>1 [Reference]</td>
<td>145.8</td>
<td>0.81 (0.78-0.83)</td>
<td>&lt;.001</td>
<td>138.4</td>
<td>0.77 (0.74-0.79)</td>
</tr>
<tr>
<td>Kidney 428.4</td>
<td>1 [Reference]</td>
<td>328.3</td>
<td>0.77 (0.75-0.78)</td>
<td>&lt;.001</td>
<td>326.7</td>
<td>0.78 (0.75-0.78)</td>
</tr>
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</table>

| **Adjusted Waiting List Registration Rates** |                        |               |              |               |                 |               |
| **Listings per Million** | RR (95% CI) | **Listings per Million** | RR (95% CI) | **P Value** | **Listings per Million** | RR (95% CI) | **P Value** |
| Heart 50.6 | 1 [Reference] | 47.3 | 0.94 (0.88-0.99) | .03 | 46.0 | 0.91 (0.86-0.96) | .002 |
| Liver 173.2 | 1 [Reference] | 156.1 | 0.90 (0.87-0.93) | <.001 | 148.7 | 0.86 (0.83-0.89) | <.001 |
| Kidney 383.4 | 1 [Reference] | 358.4 | 0.93 (0.91-0.96) | <.001 | 354.7 | 0.92 (0.90-0.95) | <.001 |

Abbreviations: CI, confidence interval; RR, rate ratio.

*Listings per million population for a zip code with median household income = $31 400; percent female = 51.2; percent age 0-17 y = 25.6, 18-34 y = 23.7, 35-49 y = 23.0, 50-64 y = 14.4, ≥ 65 y = 13.3; percent black = 12.1, Asian = 3.5, Hispanic = 11.2, and other race/ethnicity = 0.9. Quantiles equal US average/median for these characteristics.

*Adjusted rate ratio is derived from a multivariate regression analysis using a Poisson distribution to control for population demographic differences at the zip code level (age, race, sex, and median household income).
States. While the degree of disparity differed by region, the pattern of reduced access to transplantation was seen across all OPTN regions for each organ studied.

**Time to Transplant Models and Survival Following Transplant**

Once wait-listed, residents of small towns and isolated rural regions did not wait longer than urban patients for liver (hazard ratio [HR] = 0.96; 95% CI, 0.91-1.03; \( P = .24 \)) or kidney transplants (HR = 1.03; 95% CI, 1.00-1.06; \( P = .05 \)). Conversely, small town/isolated rural residents listed for heart transplant waited longer and were significantly less likely to receive a transplant than their urban counterparts (HR = 0.85; 95% CI, 0.76-0.94; \( P = .002 \)).

There were no significant differences observed in posttransplant outcomes based on location of residence by RUCA group. Rural residence was not associated with the time to death following heart (HR = 1.02; 95% CI, 0.89-1.17; \( P = .75 \)) or liver (HR = 1.01; 95% CI, 0.92-1.10; \( P = .92 \)) transplant or the time to kidney graft failure (HR = 0.99; 95% CI, 0.93-1.05; \( P = .74 \)).

**COMMENT**

This study demonstrates that patients living in small towns and isolated rural regions were 8% to 15% less likely to be wait-listed and 10% to 20% less likely to undergo heart, liver, and kidney transplantation than patients in urban environments. These discrepancies may be related to differences in the burden of disease in rural environments or reduced access to entering the waiting list.

Once wait-listed for transplant, rural patients awaiting liver and kidney transplant receive organs at the same rates as patients in urban areas. There are also no major differences in outcome following transplantation between urban and rural residents.

**Observed Disparities and Potential Barriers to Transplant**

The observed disparities in population-based rates of transplant may reflect barriers faced by rural patients in completing a complex referral and evaluation process. Completion of the transplant evaluation has previously been identified as a barrier for other disadvantaged populations, including racial minorities, women, and poor individuals. Patients must first be deemed medically suitable by their local physician, express an interest in transplantation, obtain a referral, complete a medical and surgical evaluation prior to wait-listing and again before undergoing a transplant once a donor is identified. Alexander and Sengal analyzed this process and determined that completion of the pretransplant evaluation, which may require several visits for sophisticated testing, posed the greatest barrier for previously identified disadvantaged groups. This conclusion was similar to that of Weng et al who prospectively evaluated 175 patients initially evaluated at a major urban transplant center. Among these patients, 43% failed to complete the pretransplant evaluation. The primary risk factor for an incomplete evaluation was African American race. However, these authors did not examine distance to the transplant center in their analysis. It is plausible that rural residents face greater economic and travel barriers to completion of the evaluation, which may contribute directly to lower wait-listing rates.

Delayed referral to specialists, which is common in rural populations, has also been associated with decreased access to transplantation. Currently, 25% to 40% of the population of patients with end-stage renal disease in the United States, United Kingdom, and Australia initiate dialysis within 4 months of initial nephrology referral, a time frame that is defined as a delayed nephrology evaluation. Delayed nephrology evaluation is associated with lower survival of patients treated by dialysis, a higher incidence of comorbid conditions, and a significantly lower likelihood of being placed on the waiting list for transplantation: 61% of patients referred early are wait-listed vs 45% of those referred late. Re-

**Table 3. Unadjusted and Adjusted Transplant Rates for Heart, Liver, and Kidney Transplantation for 5-Year Cohort**

<table>
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<tr>
<td>Liver</td>
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<td>Kidney</td>
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| **Rural/Small Town** |
| Listings per Million | RR (95% CI) | \( P \) Value (vs Urban) |
| Heart | 33.1 | 1 [Reference] | 31.2 | 0.94 (0.89-1.00) | .07 |
| Liver | 81.4 | 1 [Reference] | 66.5 | 0.84 (0.80-0.87) | <.001 |
| Kidney | 242.5 | 1 [Reference] | 218.1 | 0.88 (0.86-0.90) | <.001 |

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| **Rural/Small Town** |
| Listings per Million | RR (95% CI) | \( P \) Value |
| Heart | 33.1 | 1 [Reference] | 29.0 | 0.88 (0.81-0.94) | .004 |
| Liver | 81.4 | 1 [Reference] | 65.5 | 0.80 (0.77-0.84) | <.001 |
| Kidney | 242.5 | 1 [Reference] | 219.2 | 0.90 (0.88-0.93) | <.001 |

Abbreviations: CI, confidence interval; RR, rate ratio.

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cent studies in liver transplantation suggest a similar pattern of delayed referral, particularly for vulnerable populations. Within the Veterans Administration system, an examination of records of 199 patients with cirrhosis of the liver and eligible for referral to a liver transplant center (American Association for the Study of Liver Disease criteria), revealed that liver transplantation was discussed with only 21% of patients. Factors associated with failure to discuss transplantation included older age, alcohol-induced liver disease, and African American race. At the University of Alabama in Birmingham, Eckhoff et al also identified a pattern of disproportionately low referrals of African Americans for liver transplant. Furthermore, African American patients who were referred for transplantation evaluation had more advanced liver disease and were more likely to be critically ill.

Distance to the transplant center may play a pivotal role in the impaired access to transplantation faced by rural residents. In a previous investigation of the impact of distance on liver transplantation using a single-state hospital discharge database, the rate of liver transplants per admission for liver disease for residents of counties more than 250 miles from a transplant center was 80% lower ($P<.001$) than for residents living in the county with a transplant center. In a study from Ireland, the combination of residence remote from the transplant center and lack of private (no governmental option) health insurance was associated with markedly lower liver transplant access. There was no disparity of access by insurance status among residents who lived near the transplant center.

**Limitations**

This analysis has several potential limitations. First, the reported rates are based on total population rather than a disease-specific population. Thus, a criticism of the methodology is that rates of end-stage organ failure are adjusted for age, sex, race, and median household income could vary sufficiently to explain the observed differences. Although rural residents tend to be older, less well-educated, and more likely to have chronic diseases, the incidence of end-stage renal disease appears to be similar across regions, with 22% of incident cases occurring outside of major urban areas. Similarly, in an analysis of liver transplantation in North Carolina, Tuttle-Newhall et al found no difference in admission rates for liver disease in patients who lived in rural vs urban counties.

There are no recent national data available regarding possible differences in the incidence of cirrhosis by rural or urban residence, but some factors associated with higher rates of cirrhosis include older age, lower educational achievement, obesity, and alcohol abuse, all of which are more prevalent in rural populations. Evaluation of the incidence of heart disease throughout the United States confirmed a 12% higher rate in rural counties when compared with urban areas. In the South, the incidence of heart disease is nearly 20% higher in rural counties than urban areas. The issue of delayed wait-listing after diagnosis may explain some of these findings but using this data set, we could not quantify the time from diagnosis to listing for transplantation faced by rural patients. Further characterization of epidemiological differences in disease burden among potentially disadvantaged populations, including those living in rural areas, is needed to more accurately target health care resources.

Second, although it is not possible to account for patient preference or other cultural factors that may discourage rural residents from seeking transplant care, it is imprudent to assume that patient preference explains differential access. For example, while a significant number of physicians reported that patient preference was in part responsible for differential referral of African American as compared with white dialysis patients for kidney transplantation, direct patient surveys revealed no significant differences in desire for transplant based on race.

Third, it is possible that a small number of rural patients have moved to urban areas to secure a transplant. However, this analysis was performed using the zip code of residence at the time of initial wait-listing. Thus, even if rural patients moved closer to urban transplant centers during the course of their illness to await transplantation, they would still have been classified as rural patients in our study. Among patients who present with rapid deterioration, it is unlikely that they would move their established residence during the acute period of their illness.

Finally, although our analysis controlled for several demographic factors, it is possible that there are other important unmeasured differences between rural and urban populations. It is likely that the combination of inadequate insurance coverage, low socioeconomic status, and distance may impose a disproportionate burden on rural transplant patients that may prevent them from completing a necessary transplant evaluation and gaining access to the waiting list.

Although this disparity identified in transplantation among rural populations is similar in character to that faced by other groups, current strategies to improve access to transplantation may have limited efficacy in rural populations. Recently, organ allocation policies have been changed for deceased donor kidney transplantation to reduce the importance of donor and recipient HLA matching. This change has resulted in improved transplant access for wait-listed African Americans, who represent a disproportionate share of the kidney waiting list compared with their rate of donation. However, it is unlikely to improve access to the waiting list or to transplant for rural residents who, in most parts of the country, tend to be predominantly white. Other initiatives, including increased oversight of dialysis units to ensure adequacy of transplant referral, may assist patients receiving care in rural units.
improve rural residents' access to liver or heart transplant at this time. Given the lack of proactive strategies and the increasing concentration of transplant services in high-volume urban centers, it is possible that there will be increasing access barriers faced by rural patients. While our study did not examine the impact of distance per se, rural residence is a useful surrogate for greater distance, given that the majority of transplant centers in the United States are located in large cities. Large commercial insurers in the United States are steering many candidates to these large urban centers, where they may be far from social support networks and find it more difficult to complete the necessary pretransplant evaluation. Donated organs from deceased rural residents are mainly transplanted at large urban centers, which leads to a net transfer of organs from rural donors to urban recipients.  

This study could not identify whether underlying disease burden or specific barriers faced by rural residents with organ failure were responsible for the observed effects. Further assessment of the disease burden facing rural transplant recipients and the barriers in access to specialty care services is needed to ensure equitable access to life-saving organ transplants.

Author Contributions: Drs Axelrod, Finlayson, Schaubel, Chobanian, and Merion had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Axelrod, Finlayson, Schaubel, Goodman, Chobanian, Merion.

Acquisition of data: Axelrod, Goodman.

Analysis and interpretation of data: Axelrod, Guidinger, Finlayson, Schaubel, Goodman, Merion.

Drafting of the manuscript: Axelrod, Guidinger, Chobanian.

Critical revision of the manuscript for important intellectual content: Guidinger, Finlayson, Schaubel, Goodman, Chobanian, Merion.

Statistical analysis: Axelrod, Guidinger, Schaubel.

Obtained funding: Merion.

Administrative, technical, or material support: Goodman.

Study supervision: Finlayson, Schaubel, Chobanian, Merion.

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Disclaimer: The views expressed in this article are those of the authors and not necessarily those of the US government.


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REFERENCES


