Journal of General Surgery

Scient Open Access
Exploring the World of Science

Open Access Full Text Article

Research Article

Interstate Transplant Recipients Exhibit Improved Kidney Allograft Survival Compared to Natives of that State

This article was published in the following Scient Open Access Journal:
Journal of General Surgery
Received August 11, 2017; **Accepted** September 19, 2017; **Published** September 25, 2017

Meredith Scott*, Graham Mitro, Ryan Flynn, Weikai Qu, Michael Rees and Jorge Ortiz

Department of Surgery, University of Toledo Medical Center, OH, USA

Abstract

Objectives: Regional disparity in access to organs for kidney transplantation has led to inter-state "transplant tourism." Our objective is to examine demographic and outcome differences between "transplant tourists" and regional residents.

Materials and Methods: The Scientific Registry of Transplant Recipients was analyzed to examine deceased donor kidney transplants performed from 03/2006 to 05/2015 at a single institution (n=581). The recipients numbered 329 from Ohio and 252 from Michigan.

Results: The Ohio group exhibited higher incidence of diabetes mellitus (DM; 45.9% vs. 36.7%, p=0.044), lower educational attainment beyond high school (43.2% vs. 72.5%, p<0.001), and greater likelihood of receiving an extended criteria kidney (16.1% vs. 8%, p=0.008). No other demographic differences were noted.

Incidence of delayed graft functions or of rejection at 90 days or 1, 3, or 5 years was equivalent between the two groups. Michigan patients exhibited better death censored graft survival overall (81.6% vs 89%, p=0.022) and at 1-year post transplantation (92.5% vs. 97.3%, p=0.022). The Michigan group also exhibited improved patient survival overall (80.8% vs. 88.6%, p=0.018). Graft loss among Ohioans was associated with elderly (>65 years) status (19.3% vs. 5%, p=0.037), prior renal transplantation (33.3% vs. 17.5%, p=0.045) or high (>20%) panel reactive antibody (PRA; 36.2% vs. 16.3%, p=0.036). Ohio recipients also exhibited decreased patient survival with high panel reactive antibody (23.4% vs. 2.0%, p=0.002), diabetes mellitus, (30.8% vs 16.1%, p=0.021), or with a donation after cardiac death kidney (20.8% vs. 17.4%, p=0.017).

Conclusions: In this single center study, patients traveling from outside the state of transplantation exhibited similar donor and recipient demographics to Ohioans yet experienced superior allograft outcomes and were less affected by risk factors. These benefits may be tied to socioeconomic factors as evidenced by the discrepancy in education levels.

Keywords: Renal, Transplant, Demographics

Introduction

Chronic Kidney Disease (CKD) and End Stage Renal Disease (ESRD) are major health problems in the United States. The incidence of CKD in the United States was estimated at 13.6% in 2012 and the estimated cost to Medicare exceeded 87 billion dollars [1]. In that same year there were 636,905 patients treated for ESRD. The incidence continues to rise [2]. Furthermore, the number of kidney transplants has increased 78% since 2000 [3].

Equitable access to donor organs regardless of location continues to be a major goal of the transplant community. Despite this, less than 20% of patients on the transplant waitlist will receive a kidney within their first year on the waitlist [4]. Extended wait time contributes to negative transplant outcomes. Therefore, many patients list at multiple transplant centers in an effort to decrease personal wait time.

The wait time for renal transplantation in Michigan averages between 4-6 years versus 19 months in Ohio [5]. Given this disparity in wait time many patients from Michigan travel across the state line to list at Michigan and Ohio transplantation programs. Patients who have a longer wait time in their original donation service area (DSA), like our Michigan population, are more likely to seek multiple listings in another DSA with a shorter average wait time [6].

***Corresponding author:** Meredith Scott, Department of Surgery, University of Toledo Medical Center, OH, USA, Tel: (330) 604-5939, Email: Meredith.Scott@rockets.utoledo.edu

It may be expected that patients who travel greater distances, have poorer follow-up post-transplantation and therefore may have worse outcomes. However, patients who multiple-list have been shown to have higher educational and socioeconomic status' than patients who list at only one transplant program which may correlate with improved graft survival [7]. The aim of our study was to compare the patients' and graft survival of patients transplanted at the University of Toledo Medical center that were native to Ohio with those patients who travelled from Michigan.

Materials and Methods

We analyzed the Scientific Registry of Transplant Recipients to examine all deceased donor kidney transplants performed from March 2006 to May 2015 at The University of Toledo Medical center (n=581). The patients were divided into those who resided in Ohio (n=329) and Michigan (n=252). Approval was obtained from the Institutional Review Board. We excluded recipients of living donor renal transplantation from this analysis. We reviewed patient data using Trans Chart electronic medical record software (TransChart LLC, Dublin, Ohio).

Preoperative immunosuppression included: Alemtuzumab - 30mg IV, or 0.5mg/kg if less than 60kg, Diphenhydramine - 25mg IV, Methylprednisolone - 500mg IV, Mycophenolate sodium -720 by mouth (PO). The majority of recipients were steroid free. The post-operative steroid taper consisted of: methylprednisolone 250 mg IV on post-operative day 1, methylprednisolone 125 mg IV on post-operative day 2, prednisone 60 mg PO on post-operative day 3, prednisone 40 mg PO on post-operative day 4, and, finally, prednisone 20 mg PO on post-operative day 5. Prednisone at 5-10 mg PO was continued indefinitely for patients with a high risk of rejection; African American patients, patients receiving a repeat transplant or patients with a high panel reactive antibody (PRA) or who experienced delayed graft function.

Starting on post-operative day 1, Tacrolimus 1.5 mg PO (Prograf, Astellas Pharma, Tokyo, Japan) and mycophenolate sodium (Myfortic, Novartis Nutley NJ) 540 mg PO twice per day were given. Tacrolimus levels were measured and titrated to the correct dose of 4-11 ng/dL. If a patient developed an abnormal white blood cell count, Mycophenolate sodium was administered at 2/3 dose until the white blood cell count returned to normal.

Antimicrobial prophylaxis was started post-operatively with sulfamethoxazole (800 mg)-trimethoprim (160 mg) 1 tab PO (Bactrim DS, AR Scientific, Philadelphia, PA) 3 times per week and clotrimazole troche 10 mg dissolved in the mouth 4 times per day following oral care. In the event of a cytomegalovirus mismatch, daily valgancyclovir (Valcyte, Hoffman-La Roche, Basel, Switzerland) was prescribed.

Our follow up regimen is as follows: At 30 days' post-transplantation, monitor for acute rejection, post-operative complications, and adverse effects due to immunosuppressive medications every 1 to 3 weeks. Screen for adherence and the same complications listed previously every 1 to 3 weeks for months 1 to 3, then every 4 to 8 weeks for months 4 to 12 after the transplant. After one year, monitor for graft dysfunction every 2 to 4 months. Monitor for graft dysfunction and cardiovascular disease risk, cancer, adverse effects of immunosuppressive medications, general health maintenance, and adherence every 3 to 6 months. We also carry out screenings based on recommendations from the Kidney Disease: Improving Global Outcomes Organization (Table 4).

Deceased donor and recipient data were collected from the SRTR database and analyzed. Standard definitions for standard criteria donors (SCD), extended criteria donors (ECD), and CDC high risk donors were used (8, 9). Donor Kidney Donor Profile Index (KDPI) was calculated retrospectively on greater than 90% of patients on whom all necessary data elements were available. Patients who actually received a kidney transplant were analyzed, not all patients on the deceased donor waiting list.

Statistical Methods

Student's t-test or Mann-Whitney U test were used for continuous variables and Pearson's Chi-squared Test or Fisher's Exact Test for categorical variables were used for the data. Patient and graft survival were assessed using the life method. Factors associated with survival were identified using univariate Cox Proportional Hazards regression, with final multivariate models selected from the results as well as factors of interest. For multivariate models, univariate variables with $p < 0.1$ were used initially and those with $p > 0.05$ were removed at each iteration. All tests were performed at a 95% confidence interval, and a significant level of $p < 0.05$ was used. Survival curves were generated using the life table method, with statistical comparisons computed with the log-rank method. All statistical analyses were conducted using IBM SPSS ver23. (IBM Corp., Armonk, NY).

Results

Donor demographics

Both sets of recipients received demographically similar donor allografts ($p<0.05$). However, the Ohio group received more ECD kidneys (16.1% vs 8.0%, p=0.008).

Recipient demographics

There were more Asians (0.8% vs 4.2%, p=.017) and fewer Hispanics (8.6% vs. 2.2%, p=.006) in the Michigan group. The incidence of Diabetes Mellitus (45.9% vs 36.7%, p=0.044) in the Ohio group exceeded the incidence in the Michigan group. More patients from Michigan obtained an education beyond high school (43.2% vs 72.5%, $p<0.001$), obtained a college degree (10.9% vs 22%, $p<0.05$) and obtained a graduate degree (2.9% vs 16.2%, $p<0.05$) (Table 1).

Outcomes

Delayed Graft Function did not differ significantly (12.1% vs 11%, p=0.777) and the number of patients who lost allografts at 90 days, 1 year, 3 years, and 5 years were not statistically significant. The long-term death censored graft survival was not different among the two groups at 5 years (Figure 1) however the Michigan group exhibited better death censored graft survival overall (81.6% vs 89%, p=0.022) and at 1-year post transplantation (92.5% vs. 97.3%, p=0.022). Improved patient survival overall (80.8% vs 88.6%, p=0.018) was noted in the Michigan group, though this difference was not apparent at the 1, 3, and 5 year marks (Figure 2). Rejection rates did not differ significantly due to nonadherence of immunosuppressive therapy (68.4% vs 70%, p=0.854) (Table 2).

	Recipient Factors		
Factor	**Ohio**	**Michigan**	**Sig.**
Total number	329 (56.6%)	252 (43.4%)	-
Age (median)	56.5	55.9	0.523
Elderly (>65 years)	57 (22.4%)	40 (16.9%)	0.141
White	162 (63.5%)	169 (71.3%)	0.069
Black	72 (28.2%)	53 (22.4%)	0.147
Hispanic	19 (8.6%)	5 (2.1%)	**0.006**
Asian	2 (0.8%)	10 (4.2%)	**0.017**
Male sex	164 (63.9%)	150 (63.3%)	0.925
Diabetes Mellitus	117 (45.9%)	87 (36.7%)	**0.044**
Body Mass Index	28	27.7	0.41
% Private insurance	115 (45.6%)	114 (48.5%)	0.586
Education	-	-	**p < 0.001**
- Didn't finish high school	2 (0.8%)	4 (1.8%)	-
- High school	134 (56.3%)	60 (27%)	**p < 0.05**
- Some college	69 (29%)	72 (32.3%)	-
- Advanced Degree	26 (10.9%)	50 (22.%)	**p < 0.05**
- Graduate degree	7 (2.9%)	36 (16.2%)	**p < 0.05**
Education beyond High School	102 (43.2%)	158 (72.5%)	**p < 0.001**
Retransplant	66 (25.9%)	63 (26.6%)	0.918
Panel reactive Antibody>20%	47 (18.4%)	49 (20.7%)	0.57
	Donor Factors		
Factor	**Ohio**	**Michigan**	**Sig.**
Expanded Criteria Donor	40 (16.1%)	19 (8%)	**0.008**
Donor After Cardiac Death	24 (9.4%)	23 (9.7%)	0.912
Donor age	38	36	0.217
Donor Hypertension	65 (25.5%)	52 (21.9%)	0.397
Donor Diabetes Mellitus	19 (7.5%)	18 (7.6%)	0.613
Cold Ischemia Time	14	15.1	0.328
Donor Body Mass Index	26	26.3	0.242
Kidney Donor Profile Index	38	36	0.216

Table 1: Recipient and Donor Factors.

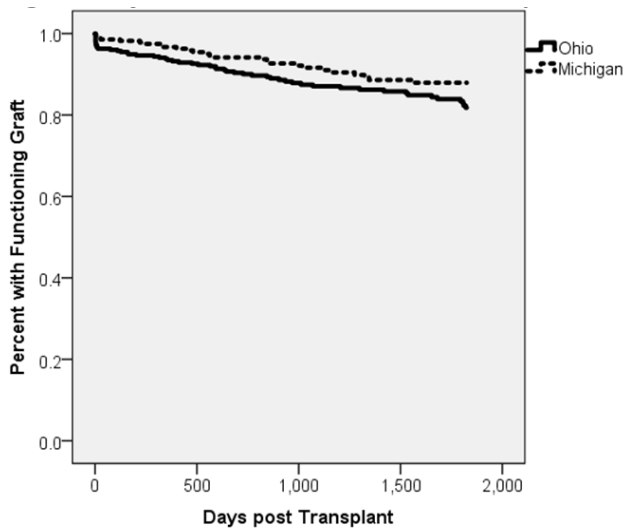

Figure 1. 5-year death-censored graft survival -p=0.032.

Despite little statistical difference among risk factors more of the patients with the same risk factors from Ohio exhibited

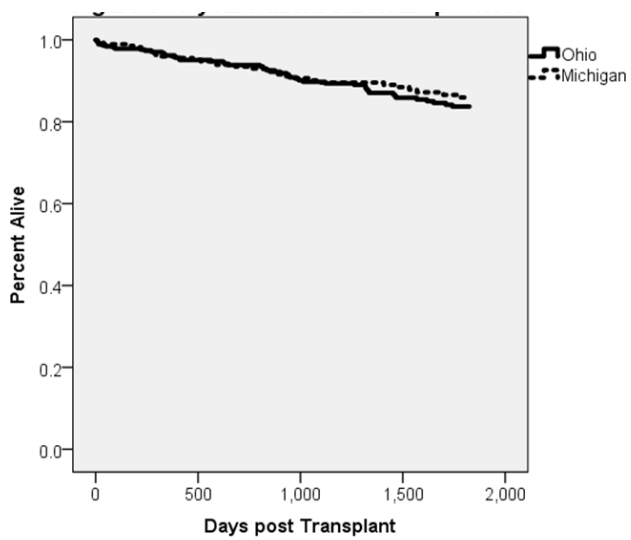

Figure 2. 5-year Patient Survival –p=0.037.

Factor	**Ohio**	**Michigan**	**Sig.**
Delayed Graft Function	30 (12.1%)	26 (11%)	0.777
Rejection (cumulative)	75 (29.4%)	61 (25.7%)	0.366
- 90 days	54 (21.2%)	41 (17.3%)	0.304
- 1 year	59 (23.1%)	50 (21.1%)	0.664
- 3 year	61 (27.8%)	56 (23.6%)	0.304
- 5 year	71 (28.4%)	59 (24.9%)	0.267
Death Censored Graft Survival (cumulative)	208 (81.6%)	211 (89%)	**0.022**
- 1 year	222 (92.5%)	216 (97.3%)	**0.022**
- 3 year	150 (87.2%)	138 (89.6%)	0.605
- 5 year	116 (80%)	100 (84%)	0.426
Patient survival (cumulative)	206 (80.8%)	210 (88.6%)	**0.018**
- 1 year	232 (96.7%(	214 (96.4%)	0.692
- 3 year	153 (89%)	141 (91.6%)	0.461
- 5 year	118 (81.4%)	104 (87.4%)	0.236
Median days:	**Ohio**	**Michigan**	**Sig.**
Rejection free	851	933	0.421
Graft survival	1322	1321	0.706
Alive	1649	1510	0.609
Days to rejection	56	39	0.595
Days to graft loss	592	696.5	0.584
Days to death	931	583.5	0.091

Table 2: Patient Outcomes by State.

worse outcomes in both graft loss and death than the Michigan recipients. Ohio patients experienced increased graft loss if they were elderly (19.3% vs 5%, p=0.037) were receiving their second transplant (33.3% vs 17.5%, p=0.045) or had a PRA greater than 20% (36.2% vs 16.3%, p=0.036). Ohio recipients also displayed increased incidence of death when the recipients PRA exceeded 20% (23.4% vs 2.0%, p=0.002), were diabetic (30.8% vs 16.1%, p=0.021), or were receiving kidneys from a donor after cardiac death (20.8% vs 17.4%, p=0.017) (Table 3). Ohio recipients showed longer median follow-up time when compared to Michigan patients (1567+/- 998.7 days vs 1315+/-915.8 days, p=0.037).

	Rejection			Graft Loss			Death		
Factor	**Ohio**	**Michigan**	**Sig.**	**Ohio**	**Michigan**	**Sig.**	**Ohio**	**Michigan**	**Sig.**
Elderly	15 (26.3%)	8 (20%)	0.628	11 (19.3%)	2 (5%)	**0.037**	15 (26.3%)	8 (20%)	0.628
Delayed Graft Function	17 (56.7%)	11 (42.3%)	0.422	6 (20%)	2 (7.7%)	0.263	7 (23.3%)	5 (19.2%)	0.755
Retransplant	26 (39.4%)	17 (27%)	0.191	22 (33.3%)	11 (17.5%)	**0.045**	10 (15.2%)	8 (12.7%)	0.801
Panel Reactive Antigen>20%	20 (42.6%)	14 (28.6%)	0.201	17 (36.2%)	8 (16.3%)	**0.036**	11 (23.4%)	1 (2%)	**0.002**
Expanded Criteria Donor	12 (30%)	6 (31.6%)	0.316	13 (32.5%)	4 (21.1%)	0.54	16 (40%)	3 (15.8%)	0.079
Donor After Cardiac Death	9 (37.5%)	7 (30.4%)	0.76	2 (8.3%)	1 (4.3%)	0.933	5 (20.8%)	4 (17.4%)	**0.017**
High school education or less	38 (28.4%)	14 (23.3%)	0.49	22 (16.4%)	11 (18.3%)	0.837	29 (21.6%)	7 (11.7%)	0.113
Diabetes Mellitus	30(25.6%)	19 (21.8%)	0.62	19 (16.2%)	9 (10.3%)	0.304	36 (30.8%)	14 (16.1%)	**0.021**
Black	17 (23.6%)	19 (38.5%)	0.163	10 (13.9%)	8 (15.1%)	0.805	12 (16.7%)	4 (7.5%)	0.178

Table 3: Select Risk Factors for Negative Outcomes by State.

Screening Test	1 wk	1 mo	2-3 mo	4-6 mo	7-12 mo	>12 mo
Serum Cr	Daily	2-3 per wk	Weekly	Every 2 weeks	Monthly	Every 2-3 months
Urine Protein &/or Urine Albumin	Once---------	Every clinic visit	Every clinic visit	Every clinic visit	Every clinic visit	Every clinic visit
Complete Blood Count	Daily	2-3 wk	Weekly	Monthly	Monthly	Annually
Diabetes	Weekly	Weekly	Every 3 mo	Every 3 mo	Every 3 mo	Annually
Lipid Profile	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly
BKV NAT	Monthly	Monthly	Monthly	Every 3 months	Every 3 Months	Every 3 months
EBV NAT (seronegative)	Once	Monthly	Monthly	Every 3 mo	Every 3 mo	Every 3 mo
BP, pulse, Ht/wt.	Done at every clinic visit	Done at every clinic visit	Done at every clinic visit	Done at every clinic visit	Done at every clinic visit	Done at every clinic visit

Bia M, et al. Am J Kidney Dis. 2010;56:189-218.
Screening Intervals by Time after Transplantation

Table 4: KDIGO Recommendations for Post-Transplant Screeening.

Discussion

The US Department of Health and Human Services issued the "Final Rule" in 1998 stating, "Organs and tissues ought to be distributed on the basis of objective priority criteria and not on the basis of accidents of geography" [10]. Unfortunately, the goal of this statement has not been met. Since its institution, there has been no significant reduction in disparity based on waiting times, transplant rates, pre-transplant mortality, and organ quality [11]. Organs from a given DSA, of which there are 58 in the nation, are allocated first to the patients within that DSA. If there are no matches, the allocation expands to surrounding DSAs and eventually to the entire country to find an appropriate recipient. The problem with this system, however, is that the boundaries of the DSA are gerrymandered to fit the needs of individual transplant hospitals and therefore inhibit equal access to organs. Certain DSAs have sicker populations and therefore have a higher need for organ transplants without an increase in donors, leading to longer wait times [11]. This is particularly evident at our institution because of its close proximity to the Michigan border and another DSA. Patients in Michigan with a 4-6 year wait time may live less than a half hour away from Northwest Ohio, where the average wait is 19 months [5]. The substantial difference in wait time between Ohio and Michigan has led to Michigan residents becoming a significant portion of the transplanted population at our center. Our goal was to determine if these patients fared better than their local Ohio counterparts and why.

Our baseline data show that both the donors and recipients exhibit relatively similar characteristics. The data does show a difference in education levels, with more Michigan recipients receiving college education. The superior outcomes noted in our study may be a function of such socioeconomic factors. There is a positive correlation between socioeconomic status and the concept of health literacy: A patient's "ability to access, understand, interpret, and use health-related information to manage and improve health" [12]. Poor health literacy is a nationwide problem, with 36% of Americans found to be health illiterate [13,14]. The correlation between higher socioeconomic status and health literacy could explain why socioeconomic was increased in the Michigan group. Furthermore, poor health literacy correlates with a higher rate of nonadherence to post-transplant immunosuppressant therapy [2]. Nonadherence is very common with renal transplant recipients. Some studies report that as many as one-third of kidney recipients are non-adherent [13]. Nonadherence is an independent risk factor for the development of antibody-mediated rejection, the most common mechanism leading to graft failure. Furthermore, graft loss can be contributed to nonadherence of immunosuppressive drugs 47% of the time [15]. In our case, 70% of our non-compliant patients were from Ohio (42 vs 18). Therefore, one could extrapolate that the Michigan patients, because of their higher education and socioeconomic status, also have higher health literacy and therefore may have better outcomes due to better adherence post-transplant.

Multiple listing does provide a solution to the long wait times in DSAs, but it also creates many issues post-transplantation. Receiving a transplant at a different institution proves very strenuous, time consuming and expensive for patients. We required patients to stay in Toledo for an extended period of time immediately following the procedure. One could assume this would deter many patients in need of a transplant from listing in DSAs that are not near their home. Further extrapolation leads to the conclusions that the Michigan patients are of higher socioeconomic status because they are the only group that can afford to take the time off from work and continually travel to their follow-up appointments. A study by Davis et al.

determined that patients with lower socioeconomic status are more likely to have a longer wait time, be listed later in their disease progression, and are unlikely to list outside of their local DSA [16]. While some Michigan patients may only have to drive relatively short distances because of Toledo's close proximity to the Michigan border, some patients may have to travel significant distances. This is a problem faced all over the country. Steve Jobs, a high profile and public example of transplant tourism, traveled across the country for a liver transplant, demonstrating how personal resources can significantly affect a person's ability to obtain an organ [17]. Liver transplant recipients travelled an average distance of 580 miles outside of their original DSA. To add further significance to the distance traveled for a liver, 67% of patients who were on multiple transplant lists received their organ from the second DSA on which they were listed [7]. A significant number of patients who are listed in multiple DSAs end up receiving their organ from a site outside of their DSA and are required to travel a significant distance to receive their care.

This reiterates the question of equal access relative to geography, and both personal and national resources. Multiple studies have shown that geography plays a role in access, despite the Final Rule [18-20]. The disparity in access can be demonstrated by comparing DSA wait times. Between the 58 DSAs in the country, the median time to transplantation varied from 0.61 to 4.57 years [16]. The Final Rule attempted to even out the distribution of organs and decrease the disparities in time spent on the wait list between regions. However, the Final Rule has not accomplished this goal. Furthermore, DSAs with longer wait times use more kidneys with a higher KDPI, extended criteria donors, and donors with hepatitis C [16]. These areas are forced to use lower quality kidneys due to the higher demand and insufficient supply, leading to worse outcomes for transplant recipients. Patients in DSAs with long wait times and lower transplant rates have lower graft and patient survival [16,19].

Race also plays a role in time spent on the wait list, with the median wait times of minorities nearly twice those of whites. Vranic, et al. hypothesized that minorities are more likely to live in an Organ Procurement Organization (OPO) area with a longer wait, indicating that geography is a bigger obstacle relative to race [20]. The data from this study demonstrates that when other variables are corrected for, geographic location of waitlisted candidates plays the most important role in racial disparities in wait times for deceased donor kidney transplantation [20]. The average wait time between minority and Caucasian candidates within an OPO differed only by 38.4 days compared to a national difference of 346 days for all candidates on waitlists. At an OPO level racial disparities are not nearly as apparent, including 14 OPOs with shorter wait times for minorities. Uneven geographic distribution of minorities plays a major role in the disproportionately longer time minority candidates spent on the waitlist nationally. At an OPO level, the distribution system is relatively fair as differences in wait times within each OPO remained generally small [20].

African Americans, despite only making up 12.6% of the population make up 44% of the ESRD population [21,22]. It has been shown that areas that have large populations of people with ESRD also have lower transplant rates of ESRD patients [23]. DSAs with a greater demand due to large ESRD populations result in longer wait times because of an organ supply that can't keep up with the need, indicating that residing in a DSA with a large minority population is a major contributor to wait time. The disparities in wait time will continue as long as geographic region determine a person's access to organs.

In December 2014, the Organ Procurement and Transplantation Network made significant changes to guidelines for the first time in 26 years with the goal to give higher priority to younger and healthier patients in order to optimally match kidneys and to decrease racial and socioeconomic disparities [24]. It remains to be seen how the new changes will actually affect wait times. One change adopted by Tennessee and Florida in 1992 has shown favorable outcomes. These two states adopted statewide sharing instead of the utilizing DSAs for organ distribution. This new policy, outlined by the United Network for Organ Sharing, actually decreased regional disparity in organ allocation [25]. Tennessee saw the most drastic changes with a drop in the disparity ratio for transplant rates from 3.39 to 1.10, a drop in waiting time from 2.31 to 1.15, and a drop in dialysis time from 1.45 to 1.04 between 1987 and 2009 [25]. Tennessee also saw a drop in cold ischemia time from 15 hours in 1987 to .49 hours in 2009. [25] Florida saw a similar decrease in disparity indicators, transplant rate, waiting time, dialysis time, and 5-year graft survival, albeit a more gradual change [25]. Other changes have been proposed including changes to allocation borders and multiple listings which could affect geographic disparity more directly. However, as with any change that helps one group, other groups are likely to suffer.

Our study shows that the Michigan recipients may have better outcomes in terms of graft survival and fared better than their Ohio counterparts when they shared the same risk factors. The decreased death and decreased graft loss of Michigan recipients even though they faced the same risk factors could indicate that being from Michigan is a potential protective factor, but this needs to be studied further to make a definitive conclusion.

The strengths of our study include its comprehensive, single-center nature, including data from every patient transplanted with a deceased donor kidney at our center for ten years, with long term follow up. We examined a large number of variables and identified those which were significantly different between groups, most notably education.

Limitations of our study are that it was a retrospective study. We only examined patients who received a transplant, and did not look at survival of all listed patients, or all those on chronic dialysis. We did not examine the difference between Michigan patients who received a transplant at our center versus those who remained on the list in Michigan, though this could be an area of future study.

Our assumption would be that the Michigan patients who traveled outside of their DSA would have better outcomes than those who stayed in Michigan due to shorter wait list times. There would also likely be differences in baseline patient characteristics among those who sought multiple listing. We recognize that this information remained outside of the scope of our current study but see it as an area for future research.

Patients travelling across a state line to receive a kidney transplant have graft survival equal to or better than local recipients and are less effected by common renal transplant risk

factors. Socioeconomic factors including education most likely play a role in this outcome.

References

1. Saran R, Li Y, Robinson B, et al. US Renal Data System 2014 Annual Data Report: epidemiology of kidney disease in the United States. *Am J Kidney Dis*. 2015; 66(3):545.
2. Demian NM, Shapiro RJ, Thornton WL. An observational study of health literacy and medication adherence in adult kidney transplant recipients. *Clin Kidney J*. 2016;9(6):858-865.
3. Williams A, Low JK, Manias E, Crawford K. The transplant team's support of kidney transplant recipients to take their prescribed medications: a collective responsibility. *J Clin Nurs*. 2016;25(15-16):2251-61.
4. Colovai AI, Ajaimy M, Kamal LG, et al. Increased access to transplantation of highly sensitized patients under the new kidney allocation system. A single center experience. *Hum Immunol*. 2017.78(3):257-262.
5. KidneyLink. Accessed 10/04/16.
6. Axelrod DA, Dzebisashvili N, Schnitzler MA, et al. The interplay of socioeconomic status, distance to center, and interdonor service area travel on kidney transplant access and outcomes. *Clin J Am Soc Nephrol*. 2010;5(12):2276-2288.
7. Vagefi PA, Feng S, Dodge JL, Markmann JF, Roberts JP. Multiple listings as a reflection of geographic disparity in liver transplantation. *J Am Coll Surg*. 2014;219(3):496-504.
8. Kauffman MH, Bennett LE, McBride MA, Ellison MD. The expanded donor. *Transplantation Reviews*. 1997;11(4):165-190.
9. Duan KI, Englesbe MJ, Volk ML. Centers for Disease Control "high-risk" donors and kidney utilization. *Am J Transplant*. 2010;10(2):416-420.
10. Department of Health and Human Services. Organ procurement and transplantation network, Final Rule. *Fed Regist*. 2013;78(128):40033-40042.
11. Davis AE, Mehrotra S, Ladner DP, Kilambi V, Friedewald JJ. Changes in Geographic Disparity in Kidney Transplantation Since the Final Rule. *Transplantation*. 2014;98(9):931-936.
12. 12.Taylor DM, Bradley JA, Bradley C, et al. Limited health literacy in advanced kidney disease. *Kidney Int*. 2016;90(3):685-695.
13. Dayer L, Heldenbrand S, Anderson P, Gubbins PO, Martin BC. Smartphone medication adherence apps: Potential benefits to patients and providers. *J Am Pharm Assoc*. 2013;53(2):172-181.
14. Kutner M, Greenberg E, Jin Y, Paulsen C. The Health Literacy of America's Adults: Results From the 2003 National Assessment of Adult Literacy (NCES 2006-483). U.S. Department of Education. Washington, DC: *National Center for Education Statistics*. 2006.
15. Rodrigo E, Segundo DS, Fernandez-Fresnedo G, et al. Within-Patient Variability in Tacrolimus Blood Levels Predicts Kidney Graft Loss and Donor-Specific Antibody Development. *Transplantation*. 2016;100(11):2479-2485.
16. Davis AE, Mehrotra S, McElroy LM, et al. The extent and predictors of waiting time geographic disparity in kidney transplantation in the United States. *Transplantation*. 2014;97(10):1049-1057.
17. Lamas, DJ. A Private Jet is Waiting to Take You to Your Kidney Transplant. *The Atlantic*. Oct 29, 2014.
18. Israni AK, Salkowski N, Gustafson S, et al. New National allocation policy for deceased donor kidneys in the United States and possible effect on patient outcomes. *J Am Soc Nephrol*. 2014;25(8):1842-1848.
19. 19. Aexelrod DA, Lentine KL, Xiao H, et al. Accountability for end-stage organ care: implications of geographic variation in access to kidney transplantation. *Surgery*. 2014;155(5):734-742.
20. Vranic GM, Ma JZ, Keith DS. The role of minority geographic distribution in waiting time for deceased donor kidney transplantation. *Am J Transplant*. 2014;14(11):2526-2534.
21. Rhee CM, Lertdumrongluk P, Streja E, et al. Impact of age, race and ethnicity on dialysis patient survival and kidney transplantation disparities. *Am J Nephrol*. 2014;39(3):183-194.
22. Saunders MR, Lee H, Alexander GC, Tak HJ, Thistlethwaite JR, Ross LF. Racial disparities in reaching the renal transplant waitlist: is geography as important as race? *Clin Transplant*. 2015;29(6):531-538.
23. Mathur AK, Ashby VB, Sands RL, Wolfe RA. Geographic variation in end-stage renal disease incidence and access to deceased donor kidney transplantation. *Am J Transplant*. 2010;10:1069-1080.
24. Massie AB, Luo X, Lonze BE, et al. Early Changes in Kidney Distribution under the New Allocation System. *J Am Soc Nephrol*. 2016;27(8):2495-2501.
25. Davis AE, Mehrotra S, Kilambi V, et al. The effect of the Statewide Sharing variance on geographic disparity in kidney transplantation in the United States. *Clin J Am Soc Nephrol*. 2014;9(8):1449-1460.