SOCIAL INEQUALITIES IN THE KIDNEY TRANSPLANTATION SYSTEM

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ABSTRACT

JONATHAN DAW: Social Inequalities in the Kidney Transplantation System
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Although transplantation is not a traditional topic of sociological research, these realms of inquiry have much to offer each other. This dissertation adopts a sociological perspective which situates transplant candidates as participants in an allocative system with clearly defined distributive rules, while recognizing the permeation of other social institutions into this system.

Chapter 1 provides an introduction to research on social disparities in the kidney transplantation system, and is intended to introduce non-specialists to this topic.

Chapter 2 investigates the determinants of racial inequalities in kidney transplantation outcomes. Using administrative data, this analysis finds that racial inequalities in this system are primarily the result of differences in living donor kidney transplants, geographic residency, and the distribution of immunologically important genes. Because these inequalities are largely rooted outside the institutional confines of the kidney transplantation system, these findings illustrate the difficulty of constructing a race-neutral institution in a racially stratified society.

Chapter 3 adopts a similar research design to investigate socioeconomic inequalities in kidney transplantation. Educational attainment is linked to transplant outcomes primarily through the type of transplants obtained. Higher educated candidates
are advantaged by their higher rates of living donor kidney transplantation and higher probability of genetic compatibility with deceased donors, whereas lower educated persons are advantaged by their places of residence and the dynamics of immunological crossmatching.

Chapter 4 uses data on the attributes of the kidney transplant waiting list and population data on the distribution of biologically-informed kinship ties and health statuses to investigate the likely distribution of suitable living donors within the kinship networks of persons on the kidney transplant waiting list. The results suggest that black-white disparities in living donor kidney transplantation are not the result of group differences in the availability of suitable donors in their kinship networks. Given the sparse number of potential donors most transplant candidates have evaluated, however, it is likely that the higher probability that white kin are suitable donors is a major determinant of racial differences in living donor kidney transplantation rates.

Chapter 5 concludes the dissertation by discussing the primary themes of this research.
To all my kin, and especially my parents, Debra Joyce and Randall Arlan Daw, and my brothers, Jesse Clay, Jeremy Patrick, and Phillip Joel Daw.
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ABBREVIATIONS

ACS  American Community Survey
CKD  Chronic kidney disease
DDK  Deceased donor kidney
DDKT Deceased donor kidney transplant
ECD  Extended criteria donor
ESRD End-stage renal disease
HLA  Human leukocyte antigen
IBD  Identity by descent
IBS  Identity by state
KT  Kidney transplant
LDKT Living donor kidney transplant
OPO  Organ procurement organization
PRA  Panel reactive antibodies
RR  Risk ratio
STAR Standard transplant analysis and research
UNOS United Network for Organ Sharing
XM  Cross-match
Chapter One: Understanding Social Inequality in the Kidney Transplantation System

Suppose that, prior to the recent health care debate, the president of the United States approached you and asked you to design the health care system from scratch. What would you do? As we learned in 2009, there is sharp disagreement on this subject. However, if you were a Democrat, you would probably start by instituting a single-payer health care system, in which the government uses its tax base to pay for health care for everyone who needs it. You might also recognize that, while the government controls vast financial and institutional resources, the supply of therapeutic goods such a system could provide would sometimes be limited. In such cases, you may well want to design the system in such a way that limited resources are distributed equitably across major social groups among those in need of them, even if doing so was slightly less efficient than other alternatives.

Often lost in the 2009 health care debate was the fact that, for a significant portion of this country’s population, universal health insurance coverage is already a reality. Persons older than 65, military veterans, and persons with end-stage renal disease (permanent kidney failure, abbreviated ESRD) are already eligible for universal health insurance provided by the federal government. Medicare coverage is available to about 45 million people¹ in the U.S., including nearly everyone with ESRD, and the Veterans’

Affairs coverage is available to the approximately 23 million U.S. veterans alive\(^2\) today. Although these three groups certainly overlap to some degree\(^3\), this means a very large proportion of the U.S. population is eligible for free, government-funded health insurance.

Persons with ESRD in this country can get free dialysis coverage for life through Medicare and, should they pursue a kidney transplant (a superior therapy), the costs of transplantation and some of the costs of post-transplantation medical care are covered, as well. Unfortunately, though, there is a shortage of organs for transplantation in this country, meaning that the number of ESRD patients awaiting a transplant exceeds the number of deceased donor kidneys available for transplantation. While some patients also obtain kidney transplants from living donors, this practice has not been sufficiently prevalent to cover the shortfall.

A shortage of resources creates a difficult problem of allocation – when distributing kidneys donated by deceased persons, to whom should these life-saving resources be given? When deciding these questions, the United Network for Organ Sharing (the government contractor charged with administering the organ transplantation system in the U.S., abbreviated UNOS) attempts to balance two key principles: efficiency and equity. Efficiency in this context means that they seek to award kidneys to patients who will most benefit from them; equity means that they seek to ensure that members of major social groups have equal access to this life-saving therapy. They do so by designing an allocation algorithm intended to appropriately balance these two maxims.


\(^3\) If we assume that half of military veterans are covered by Medicare, this suggests that approximately 18% of the country is currently covered by universal eligibility health insurance. Of course, this calculation ignores Medicaid enrollment, but eligibility for that program is largely need-based.
One might think that a health care system distinguished by universal health insurance and an institutional commitment to equality in outcomes would result in small or non-existent social inequalities in health outcomes. Unfortunately, one would be mistaken. For instance, white patients on the kidney transplant waiting list obtain kidney transplants at substantially higher rates than members of most racial and ethnic minority groups, and those whites who obtain kidney transplants obtain them much more quickly on average than their non-white counterparts (Gordon et al. 2010; Hall et al. 2011). Furthermore, white patients are less likely to die while awaiting a transplant (or after obtaining one). Major inequalities in outcomes are also observed by education, age, gender, and region. Why would this be?

In the context of limited resources, an institutional commitment to equity is likely to reduce the inequalities which might otherwise be observed, but in many contexts this will be insufficient to eradicate inequalities which are rooted outside of that institution. In general, the following are prime candidates to explain the very large social inequalities observed in the kidney transplantation system: the odds of a) successfully enrolling in the kidney transplantation waiting list, b) obtaining a living donor transplant, c) obtaining a deceased donor kidney transplant (and factors influencing one’s place in the allocation algorithm), d) rejecting a transplanted kidney, or e) dying while part of this system. As will be seen, although kidney transplantation may seem an unusual topic of sociological research, many of the factors influencing social inequalities in this system are familiar to sociologists – for instance, the social distribution of ill health, family and kin structures and dynamics, residential structure, attitudes toward treatment options, and variability in the means by which patients navigate complicated institutions appear to play substantial
Inequalities in the Path from Health to Transplantation

There are a number of important stages involved in the path from being a healthy member of the population to seeking and possibly obtaining a kidney transplant, and social inequalities are observed at each of these stages. This process is depicted in Figure 1. First, one develops a form of chronic kidney disease (CKD), which may then develop into ESRD (a more severe version of the disease; step A). The prevalence of CKD and ESRD has been growing rapidly in the U.S., driven primarily by sharp growth in the prevalence of diabetes, hypertension, and overweight – trends which have disproportionately affected the low educated, male, and African American subpopulations (Norris and Agodoa 2005). Second, to enroll in a dialysis center, pursue a kidney transplant, or both, one must be referred to and evaluated by a nephrologist (a doctor specializing in kidney disease) and decide whether to pursue a transplant or dialysis alone as treatment (step B). Conditional on having ESRD, African American and lower educated persons are much less likely than whites or higher educated persons to do so (Epstein et al. 2000).

If one decides to pursue a kidney transplant, one’s nephrologist must determine whether one is a suitable candidate, and then one must then enroll in one or more kidney transplant waiting lists (step C). Waiting lists are organized locally, and one is free to enroll in whichever and how many waiting lists one wishes, conditional that one is able to travel to a transplant center within that locality when required. Once more, non-white and lower educated persons are less likely than their counterparts to enroll in a waiting list.
(Epstein et al. 2000; Patzer et al. 2009). Furthermore, white and higher educated persons are more likely to enroll in more distant waiting lists with shorter waiting times, and are more likely to enroll in more than one waiting list (Axelrod et al. 2010; Kasiske et al. 1998; Keith et al. 2008; Merion et al. 2004), practices which offer significant advantages in the allocation system.

Once one is on the waiting list one may experience a variety of outcomes (step D). Obviously, one may succumb to kidney disease and die. Second, one may obtain one of two different types of kidney transplants, from kidneys donated by deceased persons (known as deceased donor kidney transplants, or DDKTs) or by living persons (known as living donor kidney transplants, or LDKTs). Compared to DDKTs, obtaining an LDKT is associated with improved post-transplantation outcomes and shorter average waiting times\(^4\). In keeping with the themes of this literature, white and higher educated persons are more likely to obtain any transplant, and are especially more likely to obtain an LDKT, while disparities in rates of DDKT are generally much smaller or reversed, although generally Asian and African Americans have longer DDKT waiting times than whites (Hall et al. 2011).

Finally, once one has obtained a kidney transplant one eventually experiences one of two outcomes – graft failure (better known as kidney rejection; step E) or death (whether due to graft failure or unrelated causes; step F). Once more, white and higher educated persons avoid graft failure for longer periods on average than their counterparts, and live longer post-transplantation (Gordon and Caicedo 2009). Conditional on experiencing graft failure, one may then either turn to dialysis alone or seek to return to the waiting list for another transplant (step G).

\(^4\) http://www.unos.org/docs/Living_Donation.pdf
Taken together, this research convincingly demonstrates that, compared to racial and ethnic minorities and patients with lower socioeconomic status, white and higher educated patients are advantaged at all stages associated with kidney transplantation. Compared to their counterparts, such persons are a) much less likely to develop kidney disease, b) less likely to have it develop into ESRD, c) more likely to be successfully referred to a nephrologist and be deemed a suitable candidate for transplantation, d) more likely to enroll in the waiting list and to do so in an advantageous manner, e) more likely to obtain a transplant and avoid death, f) more likely to obtain the preferred type of transplant (LDKTs), and g) have more favorable average outcomes after transplantation. A closer examination of the process and determinants of DDKT and LDKT, contextualized within the relevant sociological literature, should provide a clearer explanation of these troubling patterns of outcomes.

**Getting a Deceased Donor Kidney Transplant**

Deceased donor kidneys become available for transplantation when individuals experience brain death and their next of kin consent to organ donation. Although deceased donor kidneys may be designated for a specific recipient, typically deceased donor organs enter the general pool for allocation transplant candidates. This distributive choice is made by UNOS, guided by an allocation algorithm which is revisited periodically.

**The Current Kidney Allocation System**

Figure 2 depicts the current UNOS standard allocation algorithm. Patients are prioritized for kidney transplantation according to a set of criteria which hinge on the characteristics of patients and the joint properties of donors and each candidate. Higher
priority patients are offered each kidney first; if the kidney is declined it is offered to the next-highest priority case, and so on. As such one’s prospects for obtaining each individual DDKT depends on one’s characteristics, the match of one’s characteristic with the donor in question, and the characteristics of other members of the kidney transplant waiting list. This situation creates a unique form of social structure which determines one’s prospects for obtaining a DDKT.

One’s prioritization for each donor kidney may be grouped into four tiers. The highest priority is given to patients who are a perfect match with the deceased donor on both alleles at three different genetic loci, known as the human leukocyte antigen (HLA) genes \( HLA-A, HLA-B, \) and \( HLA-DR \). Greater similarity between donor and patient at these loci helps to prevent kidney rejection post-transplantation, and perfect matches at these loci are especially valued. Second, those who have previously served as a living donor are prioritized, followed by persons in a local area (known as an organ procurement organization catchment area, or OPO) to which the donor’s area owes a kidney of that blood type. If no such persons exist on the waiting list or accept the transplant offer, kidneys are offered sequentially to patients in the same OPO as the donor in priority order, followed by those in the same region, and then all remaining members of other waiting lists.

Second, candidates with an identical blood type (coded genetically by the \( ABO \) gene) as the donor are prioritized, followed by candidates with type B blood if the donor is type O, followed by all others with compatible blood types. Blood type is an important determinant of post-transplant prospects for the same reason that it is a crucial consideration in blood transfusions – in the absence of preventive measures, kidneys
transplanted into someone with an incompatible blood type are nearly invariantly and immediately rejected by the recipient’s immune system. Once more, one’s genetic similarity to the DDKT pool serves as an important feature of the social structure of the kidney transplantation system.

The third tier of the allocation system ranks patients by their age and degree of immunological sensitivity (measured by one’s Panel Reactive Antibody score, or PRA). The more presensitized one’s immune system is, the greater the likelihood that one’s body will reject a randomly transplanted kidney, so patients with greater immunological sensitivities are prioritized to partially ameliorate this source of disadvantage. The primary determinants of one’s PRA score are prior transplants, blood transfusions, and pregnancy (Leffell et al. 1997), all of which involve the exposure of one’s immune system to another’s tissue. Therefore one’s health and reproductive histories, as well as one’s age, are an important determinant of one’s place in the social structure of kidney transplantation.

Finally, the fourth tier of prioritization differentiates patients who are otherwise identical in the previous tiers of the allocation scheme. First, patients are awarded one point for each HLA-DR allele that matches the donor’s. Second, children younger than 11 are awarded greater priority than those 11-17, and all children are prioritized over adults if the donor is younger than 35 (because many older adults’ kidneys would not mesh well with children’s physiology). Finally, one is awarded one point per year one has spent on the waiting list, and if there are still ties between candidates, the earliest enrollee is prioritized.

Prioritization as Social Structure
Sociology has long concerned itself with the rules of allocation systems (e.g., Davis and Moore 1945). For instance, this research tradition considers each job, enrollment slot at a university, and role in the family to be a social position which is filled with individuals according to a (usually ill-defined) set of social principles. While to date there is no consensus on what the allocative ‘rules’ by which these positions are filled are, sociologists have long found this a useful way to think about society and the reproduction of inequality. In the case of transplantation, however, the allocation rules are unusually transparent – they are published on the internet\(^5\)! This feature makes kidney transplantation a particularly attractive topic to study from a stratification perspective.

Directly and indirectly, these allocative rules are the primary determinants of inequalities in kidney transplantation outcomes. Within the current system, there are five proximate determinants of deceased donor kidney transplant prospects which are likely to vary by race and socioeconomic status: genetic match with the donor pool, geographic proximity to the donor pool, mortality hazards, probability of accepting a DDKT offer, and place of residence. Of these, racial differences in genetic match, offer acceptance, and place of residence all explained a substantial portion of racial inequalities in DDKT (Daw 2011).

Although UNOS cannot directly control whether patients accept a transplant offer, they run a system wherein one’s genetics and place of residence play a major role in one’s transplant prospects. These are not mandatory elements of the kidney transplant social structure. In fact, to their credit, over time UNOS has eroded the role of genetic compatibility in the allocation algorithm in the interests of promoting racial equity in

outcomes (Port et al. 2004; Roberts et al. 2004). Furthermore, in 1998 then-Department of Health and Human Services Secretary Donna Shalala proposed a set of changes (known as the Final Rule) to the policies governing organ allocation. These changes would have, among other things, required the elimination of the geographic factor in the allocation process, instead creating a single national waitlist. However, this change was defeated when a group of political leaders raised a furor over this provision, led by the governor of Wisconsin, Tommy Thompson, who later became Secretary Shalala’s successor (Healy 2006).

These events highlight the fact that transplantation policy is forged at the intersection of medicine, immunology, and politics. Conditional on transplantation allocation policies, group differences in transplantation outcomes arise as a result of the distribution of prioritized characteristics compared to the transplant waiting list and the donor pool, as well as the rate at which individuals in different groups engage in advantageous behaviors and their odds of dying or rejecting an organ.

**Getting a Living Donor Kidney Transplant**

In addition to obtaining a DDKT, many patients on the kidney transplant waiting list obtain LDKTs. This is possible because all humans have two kidneys, and with normal kidney function only one kidney is required to maintain one’s health. About 88% of LDKTs are the result of donation by kin; the remaining 12% nearly always come from friends and co-workers. As such the structure and properties of one’s kinship and social networks are primary determinants of one’s access to LDKTs. Furthermore, patients likely vary in the degree to which the health care system promotes, and to which they pursue, LDKTs while on the kidney transplant waiting list.
Who is a Suitable Living Donor?

Not everyone is permitted to serve as a living kidney donor when they have a relative or friend in need. In keeping with medicine’s commitment to avoid causing harm, potential living kidney donors are rigorously evaluated to determine whether they are sufficiently healthy and genetically compatible to beneficially donate a kidney to the intended recipient, and that they are volunteering to donate free from coercion⁶.

Although transplant centers vary in their evaluation process, in 2007 an OPTN committee made a set of recommendations for ‘absolute’ and ‘relative’ contraindications for living kidney donation based on a survey of nephrologists’ evaluation practices⁷. The list of ‘absolute’ contraindications include: a) being younger than 18 years old, b) hypertension, c) diabetes, d) abnormal glucose tolerance values (a measure of pre-diabetic health status), e) history of thrombosis or embolism, f) major psychiatric conditions, g) extreme obesity, h) coronary artery disease, i) symptomatic valvular disease, j) chronic lung disease, k) recent malignancies (or cancers with a long time to recurrence), l) urologic abnormalities of the kidney, m) low creatinine clearance rates (a measure of kidney function), n) peripheral vascular disease (a major predictor of poor health among older persons), o) proteinuria (another indicator of poor kidney function), p) HIV infection, q) Hepatitis C infection, and r) Hepatitis B infection. Different distributions of these characteristics among the families of members of major social groups will therefore tend to influence inequalities in the availability of living donors within these groups.

⁶ optn.transplant.hrsa.gov/PublicComment/pubcommentPropSub_208.pdf

⁷ The report was not accepted but likely reflects typical practices because it was grounded in a survey of practicing transplant nephrologists. The document is available for inspection at http://optn.transplant.hrsa.gov/PublicComment/pubcommentPropSub_208.pdf. Accessed 8/9/2011.
Additionally, as in the DDKT allocation algorithm, genetic histocompatibility in the ABO, HLA-A, HLA-B, and HLA-DR genes are highly valued because donor-recipient similarity at these loci are strongly associated with post-transplantation prospects of graft failure and death (Danovitch and Cecka 2003). Although there are only four major red blood types (A, B, AB, and O) and each is prevalent in a significant portion of the population, there are a great deal more genotypes at the HLA loci, meaning that one’s odds of finding a high quality match with an unrelated person is quite small. Accordingly patients interested in an LDKT are encouraged to approach their close genetic relatives (such as parents, full siblings, and children) first for evaluation as close relationship types offer a high probability of genetic similarity.

Finally, as discussed above many individuals have been presensitized to others’ red and white blood cell antigens, producing antibodies to defend the body against these apparently threatening cells. Although progress is being made on this front (Haririan et al. 2009), LDKTs rarely occur between positively crossmatched candidate-donor pairs.

Who Has Access to a Suitable Living Donor?

This evaluation process suggests that one’s kinship and social networks’ structure and properties are important determinants of what I elsewhere term the “living donor opportunity structure” (Daw 2011), which is defined as the presence and number of suitable living kidney donors in one’s kinship and social networks.

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8 Parents and children share at least half of their genes due to direct descent, so they are guaranteed to have a favorable HLA match degree and have a significantly increased chance of being ABO histocompatible. While full siblings share half their genes due to common descent as well, this is merely an average. At each genetic locus, in fact, there is a 25% chance that they share no alleles, a 50% chance that they share exactly 1 allele, and a 25% chance that they share both alleles by common descent. Of course, they may also share alleles due to chance (when they inherit different copies of the gene but the alleles are the same).
These hypothesized determinants are depicted on the left side of Figure 3. First and most obviously, all else equal the size of one’s network is an important determinant of the LDKT opportunity structure since every kin 18 years old and over has some non-zero probability of being a suitable donor. Second, the health of one’s kinship network is a proximate determinant thereof because potential donors with a range of poor health conditions are excluded from donation. Third, the structure of one’s network is an important determinant of one’s LDKT opportunity structure because having a greater number of close genetic relatives in one’s network improves the chances that there is a suitable living donor in one’s network. Fourth, higher PRA values, net of overall genetic compatibility, will increase the probability of donor exclusion due to immunological crossmatching.

Fifth, one can share genes with potential donors in one of two ways – by common descent (i.e., I share a gene with my brother because we inherited the same copy from my mother; this is known as identity by descent, or IBD) and by chance (i.e., I share a gene with my brother because we inherited different copies of a gene which happened to be the same; this is known as identity by state, or IBS). Although the odds of IBD compatibility are identical for all pairs of humans with the same genetic relationship, the odds of IBS are directly proportional to the degree of genetic variability in the population at that locus. Much research (Liu et al. 2006; Prugnolle et al. 2005a; Prugnolle et al. 2005b) shows that African Americans in the U.S. have greater genetic diversity overall and at the HLA loci than do whites.

In summary, one’s odds of having access to a suitable living kidney donor are directly related to one’s position in the social structure, and particularly the
characteristics of one’s kinship network. Of these factors, my recent research (Daw 2011) suggests that, compared to African Americans, white patients on the kidney transplant waiting list are primarily advantaged by their lower genetic variability and lower PRA scores, while African Americans are advantaged by the larger size of their kinship networks. On the whole, African Americans were estimated to have access to suitable living kidney donors at rates slightly higher than were whites, yet African Americans obtain LDKTs at much lower rates than whites. Why would this be?

**Who Pursues and Obtains Living Donor Kidney Transplants?**

Although relatively little research has been conducted on this topic directly, medical research on transplant candidate behaviors and sociological research on the family suggest a range of plausible explanations for this discrepancy which should be investigated in future research.

A recent study of all patients and potential donors evaluated by a single center found that about 49% of their patients brought in one or more potential donors; of these, the vast majority brought in two or fewer (Weng et al. 2010). Despite having similar numbers of potential donors evaluated among those with any, African American patients were less likely to obtain an LDKT (risk ratio=0.67), have a potential donor evaluated (RR=.86), and obtain an LDKT conditional on donor evaluation (RR=0.78). Black potential donors were more likely to be excluded for donor-related reasons. Another study (Lunsford et al. 2007) found that, out of all potential donors evaluated at their transplant center, 43% of potential donors were excluded for poor health, 10% were excluded due to positive crossmatching, and 30% did not complete the donor evaluation.
African American potential donors in this study were more likely to be excluded due to immunological incompatibility and due to high BMI (Reeves-Daniel et al. 2009).

Given the benefits of LDKT – shorter times on the waiting list and longer survival times post-transplantation – why do so few patients have potential donors evaluated? A series of ethnographic studies suggest some answers. First, many patients report, understandably, that this is a very difficult subject to broach with one’s friends and family (Barnieh et al. 2011; Rodrigue et al. 2008). Another substantial portion says that they have no one to ask for a kidney (Barnieh et al. 2011). Nonetheless, based on single-center studies it appears that approximately 80% of candidates discuss potential donation (Barnieh et al. 2011) with others and that about 50% of candidates have a potential donor evaluated (Weng et al. 2010). Factors associated with higher odds of having a potential donor evaluated included higher perceived benefits of LDKT and positive beliefs concerning the appropriateness of requesting donation (Zimmerman et al. 2006), as well as younger age, higher income, and being white (Reese et al. 2009). Although most patients appear to have kin who offer to be evaluated for donation, only about half of these patients agree to this (Gordon 2001). Three major reasons offered explaining these refusals include concerns about risks to the potential donor, an emphasis on self-reliance, and a willingness to consider the offer if their medical condition became more dire.

Other Likely Determinants

The investigations just discussed into patients’ living donor search behaviors are largely limited to behaviors taking place within transplant centers. However, the broader literature on racial and socioeconomic differences in participation in the health care
system, attitudes and knowledge of medicine, and the family suggest a number of additional plausible explanations for this difference in outcomes.

_The health care system._ First, in order for the opportunity for LDKT to be translated into an LDKT outcome, full knowledge of the health care options available to the ESRD patient must be known, usually provided by the patient’s health care provider. It may be that the likelihood that LDKT is discussed and promoted by patients’ health care providers varies by race and education in a manner that makes LDKT a more likely option for whites and those of higher SES than for blacks given their respective LDKT opportunity structures. The evaluation of potential living kidney donors is a complicated process about which the patient is likely to initially know little, so health care providers frequently serve as gatekeepers to the initiation of this process. Related research on the determinants of transplant waitlisting has found that whites are significantly more likely to complete the waitlisting evaluation process and experience shorter nephrology referral delays than blacks (Alexander and Sehgal 2001; Gordon et al. 2010). Furthermore, conditional on expert evaluations of the suitability of transplantation, whites were more likely to be considered suitable transplant candidates by their physicians than were medically similar black patients (Epstein et al. 2000). It could be that differential promotion of and guidance in the LDKT process on the part of the health care providers could explain this difference.

_Knowledge of and interest in transplantation._ Much medical research on racial differences in transplantation focus on the role of racial differences in knowledge of, and interest in, transplantation. Recently researchers (Navaneethan and Singh 2006) conducted a systematic review of the medical literature on racial disparities in kidney
transplantation. Of the eleven articles they focused on, eight focused on the differential personal and cultural beliefs of African Americans compared to whites (Alexander and Sehgal 1998; Alexander and Sehgal 2001; Ayanian et al. 2004; Epstein et al. 2000; Gordon 2001; Hicks et al. 2004; Klassen et al. 2002; Ozminkowski et al. 1998).

Thus patient preferences and beliefs are a central focus of the medical literature on disparities in kidney transplantation and a frequently cited site of potential intervention (Rodrigue et al. 2006; Waterman et al. 2006). However, the evidence on racial differences in these factors is mixed. For instance, many argue that lower awareness of the risks and benefits of transplantation mediates the racial disparity in transplant outcomes (Malek et al. 2011). An equally commonly invoked explanation is racial differences in beliefs concerning the social and religious appropriateness of transplantation (Alexander and Sehgal 2001). Other research finds that blacks are interested in transplant at slightly lower rates than whites and are less likely to be certain about this preference (Ayanian et al. 1999). Although perhaps overemphasized in the medical literature on kidney transplantation disparities, beliefs, preferences, and knowledge of transplantation are theoretically plausible mediators of the relationship between LDKT opportunity and actual LDKT.

*Kin relations.* Finally, a major and understudied potential mediator of the relationship between LDKT opportunity structures and actual LDKTs is the nature of family relationships. Transplantation involves a litany of complicated decisions balancing one’s health prospects on one route (dialysis, LDKT, DDKT) versus others, and LDKT requires that one request that another incur a small health risk and significant discomfort for one’s uncertain health benefit. As such LDKTs attain the status of a gift, one with an
unusual weight of symbolic and instrumental meanings. As with all gifts, LDKTs are passed across and potentially shape relations between giver and receiver – for better or for worse. While research on the role of kin relations in structuring the probability of a living kidney donation is sparse, much research sheds light on patterns of other forms of assistance and relationship ties in white and black families. For instance, while it is commonly claimed that racial and ethnic minorities have more closely knit kinship networks (Aschenbrenner 1975; Martin and Martin 1985; Stack 1974), other work finds that whites exchange assistance with greater frequency (Cooney and Uhlenberg 1992; Eggebeen 1992; Goldscheider and Goldscheider 1991; Hofferth 1984; Hogan et al. 1993; Hoyert 1990; Lee and Aytac 1998; Roschelle 1997), although the pattern differs for financial and instrumental support (Lee and Aytac 1998; Roschelle 1997; Sarkisian and Gerstel 2004).

In general, gifts are subject to strong norms of reciprocity, yet rarely can a gift of the magnitude of another’s organ be adequately be repaid, which potentially creates a creditor/debtor relationship between the kidney donor and recipient. Fox and Swazey’s (1978, 1992; see also Healy 2006) seminal work on the subject termed this the “tyranny of the gift” due to the strains such an extraordinary gift places on the relationship between donor and recipient. Transplant candidates’ willingness to accept such a gift may fundamentally depend on their relationships with their kin, the family’s reciprocity norms, and the perceived ability of the recipient to repay the gift in some way. As with all requests and offers for assistance, there are patterned expectations for resource exchanges (Bengtson et al. 1996; Lindblad-Goldberg 1987; Miller-Cribbs and Farber 2008; Neighbors 1997; Nelson 2000; Stack 1974; Tracy 1990), and one’s ability to fulfill
reciprocal exchange relations may influence one’s willingness to accept assistance. Given the substantial evidence that reciprocity norms are of particular importance to African Americans (Malson 1983; Martin and Martin 1985; McAdoo 1982; Miller-Cribbs and Farber 2008; Testa and Slack 2002), it is likely that group differences in kin relations, combined with a lower ability to reciprocate by other means among African Americans, could explain group differences in LDKT given the opportunity structure.

**Discussion**

Although the end-stage renal disease medical system is marked by universal health insurance and an organizational commitment to equalities in access to transplantation therapies, the kidney transplantation system produces large social inequalities in outcomes, particularly by race. I have argued that this counterintuitive result stems from the confluence of medical, immunological, political, behavioral, and familial patterns in American society which UNOS is unable to completely shut out. These findings emphasize the widespread influence of major social institutions in the situation of race and socioeconomic status in American society. Although lack of access to medical care is a major social concern in the U.S., its absence in this system is no panacea to health inequalities because social positions are deeply embedded in a network of institutions.

Kidney transplantation is a complex topic that requires knowledge outside the realm of typical sociological training. It is therefore understandable that relatively little attention has been paid to this topic in the social sciences (but see Fox and Swazey 1978 and 1992, Healy 2006, and Sharp 2006 for laudable exceptions). However, technical processes are not immune to sociological facts. By investigating topics outside the usual
purview of the social sciences, we can advance understanding of social inequalities
generally and aid those lacking sociological expertise in pursuing their laudable goals of
equitably relieving the suffering of hundreds of thousands of patients with ESRD.
References


Gordon, E. J. 2001. ""They don't have to suffer for me": Why dialysis patients refuse offers of living donor kidneys." *Medical Anthropology Quarterly* 15:245-267.


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Tables and Figures

Figure 1.1: The Path from Health to Transplantation

NOTE: ‘CKD’ stands for chronic kidney disease; ‘ESRD’ refers to end-stage renal disease. Each pathway indicates a step involved in the transition from a healthy member of the population to kidney disease and the process of obtaining a kidney transplant, or not. Boxes from which more than one arrow emerges indicate potentially divergent outcomes. Single arrows indicate steps which may or may not be taken.
Figure 1.2: The Deceased Donor Kidney Allocation System

NOTE: This figure represents the national kidney allocation priority algorithm since 2003. This does not represent local variations in allocation policy. Read left to right, each subsequent level reflects priorities within categories of the columns to the left, and categories closer to the top (for the first three levels) are higher priorities.
Figure 1.3: Hypothesized Proximate Determinants of Living Donor Kidney Transplantation
Chapter Two: The Determinants of Racial Inequality in the Kidney Transplantation System

Introduction

Much research on the determinants of racial and socioeconomic inequalities in health focuses on differential health care outcomes between the insured and uninsured (Davidoff et al. 2000; Finkelstein et al. 2011; Ross and Mirowsky 2000; Shi 2001). However, three major groups in the U.S. are subject to universal, government-funded health insurance: military veterans, the elderly, and those with end-stage renal disease (ESRD). Most Americans in the last two groups are eligible for insurance coverage through Medicare. Focusing on the latter, kidney transplantation (KT) is the preferred treatment for ESRD, yet the kidney transplantation system is beset with startling racial inequalities. Compared to whites, African American transplant candidates have been about 289% and 76.8% as likely to obtain a have ESRD and obtain a transplant, respectively. Comparable but less severe figures are observed for other racial and ethnic minority groups. The contrast between universal coverage for ESRD patients and the commitment of the United Network for Organ Sharing (UNOS, the organization charged with running the U.S. organ transplantation system) to the equitable allocation of organs for transplantation on the one hand, and the large racial inequalities in outcomes on the other, is a central puzzle of kidney transplantation in the U.S. This paper investigates the major determinants of racial disparities in KT among those on the waiting list since 2000.
The prevalence of ESRD is on the rise in the U.S., driven largely by trends in diabetes, obesity, and hypertension (Norris and Agodoa 2005). ESRD is treated with dialysis, kidney transplantation, or both in succession. KT is the preferred treatment, associated with far better outcomes than are observed for comparable persons on dialysis. KT, of course, require a kidney donor, which come in two major forms – deceased and living, of which the latter is associated with substantially improved post-transplant medical prospects.

The KT system is subject to increasing pressures. The supply (the number of deceased donor kidneys, or DDKs) and demand (the number of persons enrolling in the transplant waitlist) have both grown over time, but the latter’s growth has been far disproportionate to the former. Accordingly the waiting list for KTs has grown quickly over time – by the end of 2008, the number of patients awaiting kidney transplants had grown to 85,440, more than a 500% increase since 1988 and far outstripping U.S. population growth. Under these conditions kidney allocation is something of a zero-sum game – every DDK allocated to one individual cannot be awarded to another. This means that the transplant outcomes of all individuals on the KT waiting list are fundamentally interdependent. When one person obtains a living donor kidney transplant (LDKT), this potentially frees up a DDK for another member of the waitlist. Morbidly, every patient on the KT waiting list who dies before obtaining a transplant marginally increases others’ chances of avoiding this fate.

Under these conditions and within the current kidney allocation system (described below), a number of factors could plausibly influence racial disparities in KT outcomes. First, racial differences in waiting list mortality could create this inequality since death
precludes transplantation. Second, racial differences in post-transplant kidney rejection, known as graft failure, could account for some of this difference because those whose bodies reject their kidneys frequently return to the waitlist to seek another transplant, increasing competition for kidneys among similar persons. Third, racial differences in place of residence could mediate racial and ethnic disparities in outcomes. Waiting lists for KTs are organized locally, and kidneys for transplantation are typically allocated according to a ‘local first’ algorithm, meaning that those living in high-donation, low-ESRD regions will have better transplantation prospects.

Fourth, racial differences in LDKTs could account for some portion of racial disparities in transplantation overall. LDKTs, compared to DDKTs, are associated with improved post-transplant outcomes and are generally obtained more quickly, so this could be a significant source of racial differences in transplantation outcomes. Fifth, DDKs are offered to waiting list patients in the order that the allocation algorithm ranks patients for the kidney, but only about 2% of these offers are accepted by patients and their doctors. Racial differences in the probability of accepting a DDK offer could also mediate racial disparities in KT.

Some additional, biologically-based mechanisms could mediate this relationship. A significant component of the kidney allocation algorithm addresses genetic similarities between the donor and transplant candidate, reflecting better post-transplant outcomes among persons with similar red blood (ABO) and white blood (HLA) types. Both are associated with racial and ethnic background and could mediate racial disparities overall in transplant prospects. Seventh and finally, KT candidates vary in their degree of immunological presensitization, which frequently precludes successful transplantation.
Accordingly, racial differences in immunological presensitization could partially mediate racial differences in rates of KT overall.

This paper uses data from the United Network for Organ Sharing on KT candidates and donors 2000-2010 and information on the national kidney allocation algorithm to examine the major determinants of racial and ethnic inequalities in KT outcomes. Unlike previous investigations of the causes of racial inequalities in kidney transplantation, the present analysis accounts for the systemic nature of kidney transplantation, explicitly incorporating information on the DDK allocation algorithm alongside group-specific hazards of LDKT, mortality, and graft failure, thereby accounting for the interdependent nature of the kidney allocation system. The results of this analysis find that racial differences in living donor transplantation hazards, blood types, and place of residence are primarily responsible for racial disparities in KT outcomes.

Why Kidney Transplantation?

Kidney transplantation is an unusual topic of sociological research (but see Fox and Swazey 1992; Healy 2006), yet it highlights many key issues in the sociology of racial inequalities in health. First, trends in population health have been driving growth in ESRD for decades. While major risk factors for ESRD like diabetes, hypertension, and obesity have been relatively well-studied in the sociological (e.g., Boardman et al. 2005; Chang and Christakis 2005; Lutfey and Freese 2005), demographic (e.g., Lee et al. 2009; van den Berg et al. 2011), and public health (e.g., Finkelstein et al. 2005; McLaren 2007; Thomas et al. 2005) literatures, the downstream consequences of these trends have received scant attention in these fields. All three are large sources of morbidity in the
U.S. population and disproportionately afflict African Americans. The relative dearth of research on ESRD means that a major health consequence of these trends has not received full social scientific attention.

Second, the large and fast-growing literature on racial inequalities in health and mortality has done an excellent job to date in establishing the basic facts of health inequality (e.g., Blackwell et al. 2002; Elo and Preston 1997; Kelley-Moore and Ferraro 2004; Manton and Gu 2001; Williams and Jackson 2005) and its major social (e.g., Williams and Jackson 2005), geographic (e.g., Boardman et al. 2005; King and Bearman 2011; Morenoff et al. 2007; Roux and Mair 2010; Yao and Robert 2008), and biological (e.g., Conley and Bennett 2000; Seeman et al. 2010) mediators. Although the findings of this line of research have been invaluable, the very broad perspective on health generally adopted in this research limits progress in understanding the mechanisms of health and mortality inequalities. Ill health and mortality derive from a variety of causes through a variety of outcome-specific mechanisms. By focusing on common, specific causes of ill health, as in the present study, the diversity of mechanisms of health and health inequality can be better understood and help to enrich theories of racial health disparities.

Another frequent shortcoming of the literature on the social determinants of health is that the policy contexts in which these differential outcomes are produced are frequently ignored. Health policy research is too frequently conducted in a separate sphere from studies of health and health inequality. By explicitly accounting for kidney allocation policies, this analysis enhances knowledge of the mechanisms by which racial inequalities in kidney transplantation are created.
Finally, the case of racial inequalities in kidney transplantation emphasizes the difficulty of constructing a race-neutral institution in a racialized social system (Bonilla-Silva 1997). The United Network for Organ Sharing (UNOS), the organization charged with implementing the U.S. organ transplant allocation system, pursues the explicit goals of efficiency and equity in the allocation of these limited resources, and Medicare universally covers many of the costs of ESRD patient care. In the last decade, in fact, this organization has made significant changes to the kidney allocation system with the goal of reducing demographic inequalities in outcomes, with some success (Port et al. 2004; Roberts et al. 2004). However, large inequalities remain in this system, and this persistence highlights the difficulties of achieving institutional equity in a deeply unequal society. The most efficient allocation of kidney transplants would shuttle DDKTs to the young, the otherwise healthy, and those with the financial and social support resources to maximally maintain their health for long periods of time post-transplantation. Of course, this would not be an equitable arrangement. However, to the degree that the kidney allocation system deviates from such an allocation system in the interests of equity, it frequently does so at the expense of efficiency.

I argue that this tension between efficiency and equity is a general problem in the study of limited resource allocation systems. While there are certain to be exceptions, often in a stratified society the most efficient use of limited resources – an admissions slot at a university, a business contract, or a kidney transplant – leads to the allocation of

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9 Bonilla-Silva (1997) defined a racialized social system as one “in which economic, political, social, and ideological levels are partially structured by the placement of actors in racial categories or races” (469). Racialized social systems are hierarchical, and one or more racial groups get more than their share across a range of arenas in which outcomes are differentiated.

10 Efficiency in kidney allocation may be defined as the degree to which the allocation system maximizes the healthy life-years added to the ESRD population. Equity is a measure of the degree to which all persons with ESRD have a fair and equal opportunity to benefit from this resource.
resources to those who are already advantaged. The reason is that any allocation system which seeks in part to maximize the efficiency of resource allocation must develop criteria by which to do so, and the criteria which will maximize efficiency are frequently themselves sources of general advantage, as illustrated by the fundamental cause tradition in the sociology of health inequality (Link and Phelan 1995; Phelan et al. 2004). Therefore, those who are already advantaged in a social system will frequently benefit to the degree that institutional resource allocation emphasizes efficiency, to the detriment of equity\textsuperscript{11}.

**Racial Inequalities in Health**

Research on racial inequalities in health has thoroughly documented a convincing and consistent pattern in population health and health inequality. Broadly speaking, African Americans and Native Americans experience substantially worse health outcomes overall, are subject to earlier disease onset and greater disease severity, and on average have shorter lives than members of other groups (Elo and Preston 1997; Williams 2005), while Hispanics often have better health outcomes than whites (Franzini et al. 2001). Racial differences in socioeconomic status (e.g., Williams et al. 2010), physical and nutritional environments (e.g., Lovasi et al. 2009), lifestyle (e.g., Crespo et al. 2000), and health behaviors (e.g., Jackson et al. 2010) are thought to be major mediators of racial inequalities in health.

This literature has served as a helpful window into racial and ethnic health disparities and has documented group differences in a variety of health outcomes and causes of death. This research demonstrates that there is considerable variation in these

\textsuperscript{11} The transplantation community is well aware of this tension in their own arena. However, the argument that this principle may apply to many other resource allocation systems is a general one frequently discussed in economics (e.g., Okun 1975; Blank 2002).
patterns of ill health by cause (e.g., Singh and Siahpush 2002; Smith 2003). For instance, although African Americans are subject to higher prevalences of hypertension, diabetes, and obesity than whites, whites have higher prevalences of non-diabetic poor kidney function, cancer, and peripheral artery disease (Daw 2011). These findings suggest that the mechanisms of racial inequalities in health would be better understood if major illnesses and causes of death were explored individually and in great detail. Together, supplementing the literature on coarse differences in health outcomes by race with focused investigations into the mechanisms of illness-specific disparities ill health may significantly advance this important field of research.

**Medical Research on Racial Inequalities in Kidney Transplantation**

Although racial inequality in kidney transplantation has received relatively little attention in sociology, medical research has investigated it extensively. While there is not room to review this literature exhaustively (but see Gordon et al. 2010; Hall et al. 2011; Higgins and Fishman 2006; Malek et al. 2011; Young and Gaston 2005), a number of major themes deserve brief mention. First, this body of work emphasizes that getting a kidney transplant is a multistage process with numerous steps at which racial inequalities may arise. Once one has chronic kidney disease (CKD), ESRD may develop. Conditional on having ESRD, one may begin dialysis, pursue a KT, or both. If one pursues a KT, one must be referred to a transplant nephrologist, be evaluated for transplantation, and enroll on the KT waiting list. Finally, one may pursue a DDKT, an LDKT, or both. This literature convincingly demonstrates that racial inequalities arise at all stages of this process (e.g., Epstein et al. 2000; Hsu et al. 2003; Weng et al. 2010).
Although there are a number of exceptions, much medical research on racial disparities in kidney transplantation emphasizes the role of race differences in patient knowledge, preferences, and biology. Patient knowledge concerning the process of transplantation and their transplantation risks and options is associated with race (Finkelstein et al. 2008), and is associated with higher odds of firm interest in a KT (e.g., Vamos et al. 2009; Zimmerman et al. 2006) and of obtaining a KT (Barnieh et al. 2011). However, African Americans are less likely to proceed with transplantation even when full information on transplantation risks, benefits, and options are presented (Young and Kew 2005). Furthermore, this research frequently claims that that racial differences in cultural and religious beliefs lead African Americans to object to transplantation (Navaneethan and Singh 2006; Vamos et al. 2009), particularly LDKTs (Gordon 2001; Rodrigue et al. 2008; Waterman et al. 2006), and that these factors play a large role in racial inequality in KT. Surveys of nephrologists confirm that this is a commonly held explanation for racial disparities in KT (Ayanian et al. 2004). Finally, this line of research frequently concludes that racial differences in transplantation rates are caused in part by racial differences in the distribution of ABO and HLA types (Gebel et al. 2003; Higgins and Fishman 2006).

There is much value in studying these factors. After all, KT’s are a voluntary treatment modality, so differential views on the propriety of this therapy obviously could play a role in racial disparities in KT. Also, although progress has been made in overcoming this problem (Montgomery et al. 2011), distributional differences by race in HLA and ABO do pose obstacles to equitable transplantation outcomes. However, the overemphasis of the medical literature on these topics is an impediment to understanding
of the full range of determinants of racial inequality in KT as they are frequently insufficiently contextualized to account for patients’ position in society and the medical system.

Methodologically, this line of research is hampered by insufficient recognition that kidney transplantation is a fundamentally interdependent process, and that the nature of these interdependencies is sufficient to violate the assumptions of the majority of the methods employed in this research. Crucially, the regression models typically used in this research assume that individual outcomes are independent from one another (Lee and Wang 2003). While this could be justified for post-transplant outcomes, this is an untenable assumption in studies of waitlist outcomes in the context of a kidney shortage, which means nothing if not that patient outcomes are fundamentally interdependent.

Furthermore, this research practice generally treats the possible outcomes besides those of interest as censoring events rather than competing risks. These models require the assumption, however, that censoring events are unrelated to the risk of the event of interest (Lee and Wang 2003), which is unlikely to be true in the case of KT. For instance, while on the waitlist one is at risk of obtaining a DDKT, and LDKT, and death. It may be that rates of LDKT are related to the length of the waitlist such that individuals who expect to wait 10 years for a DDKT may pursue an LDKT more vigorously than someone who expects to only have to wait one year. Furthermore, there is evidence that patients with reservations about LDKT are more likely to consider it if their medical condition worsens (Gordon 2001). Similarly, after transplantation one is at risk of graft failure and death, and these outcomes are related for obvious reasons.
Instead of focusing primarily on the characteristics of individual patients, it is far better to study KT as a system. As discussed above, there are a number of steps in this system, each with unique social and institutional contexts which may structure individual outcomes. In addition to the complicated process by which one enrolls in the KT waiting list, a number of other contexts structure one’s chances of obtaining a KT. Most importantly for present purposes, one has a place in the kidney allocation system which strongly structures one’s odds of obtaining a DDKT. In this system (as discussed in greater detail below), perfect HLA matches are prioritized above all, followed by prior living donation, geographic proximity, and ABO compatibility. Therefore one’s genetic and geographic similarity to the deceased donor population and other transplant candidates strongly determine one’s transplantation prospects, and race/ethnicity is related to both. Other social characteristics are relevant to the degree that they influence one’s odds of enrolling in the waiting list, hazards of death and graft failure, and probability of obtaining an LDKT.

In summary, kidney transplantation is best thought of as a social system in which the rules of the game are unusually well understood, particularly in the case of deceased donor kidney transplantation. However, the major aspects of this system which are responsible for racial disparities in the KT system are not. Exploring this question is the goal of this paper.

**Background**

Between 1988 and 2007, more than 420,000 organ transplants were performed in the United States with high and steadily improving rates of success. This is more impressive when one considers that the first effective immunosuppressant drug,
cyclosporine, was not approved by the FDA until 1984. In the last thirty years, organ transplantation has shifted from an experimental and very risky procedure to become the therapy of choice for a range of ailments, resulting in numerous improved and extended lives.

Since 1984, in the United States organ allocation decisions have been entrusted the United Network for Organ Sharing (UNOS) by the U.S. government, which has done so by dividing the task among 11 subsidiary administrative regions. Within these regions subsidiary organizations known as Organ Procurement Organizations (OPOs) collect and allocate organs for transplantation according to national rules, with local variations.

Unlike other organ failures, for kidney failure there is a stopgap procedure (dialysis) which can replicate kidney functions over long periods of time. While imperfect, this procedure gives UNOS an opportunity it lacks for other transplant settings: the ability to allocate kidneys on the basis of potential long-term benefit rather than medical urgency, which is the dominant allocative principle for livers and many other organs.

**Human Immunology and Kidney Transplantation**

The role of these different allocation criteria are based on a confluence of politics and immunology. A brief introduction to human immunology is required (see Leffell et al. 1997; Morris 2001 for a more in-depth introduction to human immunology and organ transplantation) to understand the allocation system and its role in the present analysis.

**Antigens and Histocompatibility**

The primary task of an immune system is to defend host cells by destroying those foreign cells which might endanger them. To do this, of course, one must be able to
differentiate one (‘own’ cells) from the other. Among humans and many other species, a primary means by which immune systems do so is through the presentation and recognition of antigens, molecules on the outside of cells which are recognized by cells in the immune system. Cells displaying antigens shared by other host cells are deemed ‘histocompatible’ and permitted to carry on; cells displaying contradictory antigens trigger an immune response. In this sense antigens on cells are analogous to flags on ships at sea by which a nation’s ships recognize another of the same ilk.

For present purposes two forms of histocompatibility are noteworthy: red blood cell (ABO) histocompatibility and white blood cell (HLA) histocompatibility. The first should be familiar. Red blood cells display some combination of two antigens, labeled A and B, which are determined by the alleles present at the ABO genetic locus. There are three alleles at this locus which produce one of four phenotypes through a codominance/recessive pattern: A, B, AB, and O. The A and B alleles are codominant and the o allele is recessive. Therefore an AA or Ao genotype will result in the same phenotype (A antigens), a BB or Bo genotype will results in B antigens, but an AB phenotype will result in the presentation of both A and B antigens. An oo genotype, finally, displays no antigens. Because only detectable antigen mismatches trigger an immune response, an individual with AB blood may receive a blood donation from others with any blood type, anyone with O type blood may donate to anyone else, and A and B blood typed individuals may receive blood from others with their own blood type or those with O type blood.

A similar system describes white blood cell histocompatibility, governed by the human leukocyte antigen (HLA) genes: among others, HLA-A, HLA-B, and HLA-DR,
which are collectively comprise part of the major histocompatibility complex (MHC) in humans. However, in this instance the situation is considerably more complicated because of the considerable degree of polymorphism (allelic variety) found at these loci. There are a number of alleles at each locus which produce antigens which are ‘serologically equivalent’ and therefore histocompatible$^{12}$.

Still, the genetic diversity at these loci is of such a high degree that the probability of another human leukocyte cell’s antigens matching one’s own is vanishingly small between unrelated pairs. Any transplanted kidney will carry with it a certain number of ‘passenger’ white blood cells which, upon transplantation, are detected by the recipient’s immune system. If the leukocyte’s antigens are not histocompatible with the recipient’s, their presence will trigger an immune function response which frequently leads to the eventual destruction of the transplanted organ. For this reason, transplants between candidate-donor pairs which were not genetically identical did not achieve widespread success until 1984, with the development of immunosuppressant drugs which prevent the transplant recipient’s immune system from destroying the graft to the transplanted organ. As immunosuppression regimes using drugs such as cyclosporine and tacrolimus have improved the survival of HLA-mismatched transplant candidates, however, the role of HLA matching has been decreasingly emphasized in the kidney allocation system over the years. The so-called ABO barrier, however, is still rarely crossed in kidney transplantation (Morris 2001).

Sensitization

$^{12}$ Although research on this topic is ongoing, the current UNOS list of HLA serological equivalencies, summarized in Appendix 3A to UNOS policy 3, approved in September 2007, is used as the authoritative list. This is available for inspection at http://optn.transplant.hrsa.gov/policiesAndBylaws/policies.asp. Accessed 8/21/2010.
In addition to ABO and HLA histocompatibility, another way in which immunology influences transplant success is through presensitization. This occurs when the recipient’s body has already been exposed to the donor’s non-histocompatible antigens, though this does not typically result from exposure to the particular donor’s tissue. Primary sensitization occurs through one of three main mechanisms: 1) pregnancy, 2) blood transfusions, and 3) previous transplants (Leffell et al. 1997). There is no consensus on how long such sensitization persists, but it frequently appears to extend for decades.

The standard measure of immunological presensitization is the calculated Panel Reactive Antibody (PRA) score, a measure of the probability that one has produced antibodies to a random person’s antigens. Those with high PRA scores are among the most difficult to match to a suitable kidney because HLA mismatches between the donor and candidate are more frequently consequential. When one is presensitized to a donor’s antigens, a ‘positive crossmatch’ occurs, in which case the transplant is generally not conducted.

The Kidney Allocation System

Figure 1 depicts the current (as of 9/15/09) UNOS standard (high quality) cadaveric kidney allocation procedure for organ donors age 35 and older. Similar procedures are used for younger donors. This allocation formula does not depict subnational variation in allocative procedures due to space limitations. “Expanded criteria” donor (ECD, kidneys donated by those who are older or less healthy than those typically accepted; see Danovitch and Cecka 2003) organs are allocated on a similar basis, but without prioritization of pediatric patients or high-PRA patients.
In the current national allocation system, transplant candidates’ prioritizations are organized into four tiers. In each tier, higher ranking in higher tiers (depicted on the left of Figure 1) take precedence over higher rankings in lower tiers (depicted further to the right in Figure 1). With some exceptions, one’s priority ranking fundamentally depends on the joint properties of each potential donor-candidate match and one’s relative match degree compared to other transplant candidates.

The first tier of prioritization takes precedence over all others. Perfect HLA matches are given the highest priority, based on evidence that these matches result in substantially improved post-transplant medical outcomes (Morris 2001). Second, those who have previously served as living kidney donors are given additional priority, followed by matches between candidates and donors between whose OPOs a debtor-creditor relationship has been previously established. Below these priorities, geography is the primary determinant of the first tier: transplant candidates in the same OPO as the donor are given priority. If no candidates in the same OPO accept the kidney, candidates in the same region are then prioritized, followed by all remaining transplant candidates.

Given the difficulty of crossing the ABO barrier, the second priority tier emphasizes ABO compatibility between the donor and candidate. Those with the same blood type are prioritized, followed by potential matches involving candidates with a B blood type and donors with an O blood type (since type B is the rarest in the U.S. population and O is histocompatible with all other blood types). Finally, mere ABO compatibility is given the lowest priority. Candidate-donor pairs which are not ABO histocompatible are rarely awarded transplants.
The third priority tier ranks candidates based on their age and PRA. First, candidates in the highest PRA category (80-100%) are prioritized. Second, pediatric patients are prioritized over adults, and within these categories additional priority given to those with elevated PRA scores (21-79%). Finally, the fourth tier of the allocation algorithm distinguishes between patients who are similarly prioritized otherwise. First, matches on \textit{HLA-DR} are awarded one point apiece\textsuperscript{13}. Second, pediatric candidates are awarded priority (higher for those younger than 11), especially when the donor is younger than 35 (because older patients frequently have kidneys too large for pediatric patients). Finally, conditional on these factors candidates are prioritized based on their waiting time, down to the minute of waiting list enrollment if necessary. One point is awarded for each year on the waitlist, and then within-OPO waiting time is ranked in order such that no prioritization ties will be observed.

Because one’s prioritization is largely donor-specific, the ranking algorithm for kidney allocation is best thought of as a candidate-donor matrix. For each deceased donor, kidneys are offered to patients in decreasing priority order until such time as one patient, in consultation with their nephrologist, conditionally accepts the offer. The patient is then tested for positive crossmatches with the donor, and a medical evaluation is conducted to ensure that the patient is sufficiently healthy to undergo transplantation. If no crossmatch is detected and the patient is deemed suitably healthy, the transplant proceeds.

\textsuperscript{13} Previously, \textit{HLA-A} and \textit{–B} matches were awarded points as well, but with the increasing potency of immunosuppressive regimes these prioritizations have been eliminated in the allocation algorithm except in the case of perfect HLA matching across \textit{HLA-A}, \textit{–B}, and \textit{–DR} loci. \textit{HLA-DR} matching is still prioritized because, unlike \textit{HLA-A} and \textit{–B}, with modern immunosuppressant drugs matching at this locus is still associated with substantially improved post-transplant outcomes.
Data and Methods

United Network for Organ Sharing STAR Files

Since 1987, the United Network for Organ Sharing (UNOS) has collected detailed information on every organ transplant recipient, donor, and candidate in the U.S., containing information on the demographic, socioeconomic, medical status, laboratory, and medical treatment characteristics of each such person. Importantly, all ESRD patients are required to enroll in the kidney transplant waitlist, even if they have already identified a living donor. Therefore this database contains information on all legal transplant candidates and donors in the U.S. since 1987. Due to limitations in the availability of key data, the present analysis employs only transplant candidates enrolled in the KT waitlist on 7/1/2000 and all candidates and donors who entered the system subsequently. Additional enrollments for candidates already on the waiting list on 7/1/2000 were not included in the analytical dataset, and multiple waitlistings were excluded as well.

When each candidate is added to the kidney transplant waitlist, demographic (gender, area of residence, race/ethnicity, citizenship, education, age, etc.), medical, and laboratory information is collected on the patient. While the form permits multiple race categories to be entered, in the UNOS STAR file race information is coded exclusively in the following categories: white, black, Hispanic, Asian, Native American, Pacific Islander, and multiracial. In the present analysis, these categories were recoded into non-Hispanic white, non-Hispanic black, Hispanic, Asian/Pacific Islander, and ‘other’ categories. ABO and HLA typing and PRA is performed at the center at which the patient is evaluated. Information on the insurance coverage, U.S. citizenship status, educational
attainment, date of waitlist enrollment, and a wealth of health status measures were collected for all candidates.

Candidate outcomes are recorded for each of the major outcomes which can occur, along with the dates at which this occurred: DDKT, LDKT, mortality, and graft failure (kidney rejection). Information on the HLA and ABO genotypes, race, gender, date and cause of death (if applicable) and relationship with the donor (if applicable) were recorded for all deceased and living donors who entered the system during this time, along with a wealth of medical status and history information.

Missing data in this dataset were addressed by imputation using hotdeck imputation (Allison 2001; Reilly 1993) methods based on patient age, ethnicity, gender, and education. In hotdeck imputation, discrete groups are assigned to each observation (here, the demographic attributes just described), then non-missing values for the missing variables are drawn at random from other members of that group, proportionate to their representation in that subpopulation. Hotdeck imputation methods are widely used by government agencies such as the Census. Although multiple imputation and direct maximum likelihood methods are more in vogue in secondary data analysis in sociology, the very large size of the datasets involved and the low rates of missingness of key variables made hotdecking, which is a computationally more efficient imputation method, an attractive option for this study14.

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14 Rates of missingness were generally low, and nearly nonexistent for demographic variables. The average rate of missingness for the HLA genes, however, was 6.4%, but nearly all participants had at least one valid such measure per locus. Missing genetic data were not imputed; instead, following UNOS procedure in such cases, such persons were assumed to be homozygous at that locus. Two additional key variables had non-trivial rates of missingness in the dataset – OPO (29.1%) and PRA (58.7%). However, no cases were missing regional affiliation or key outcomes.
Methods

As described above, analyzing the major determinants of racial inequalities in KT poses a number of analytical challenges which render most standard regression-based analysis approaches inadequate. First, the outcomes of individual patients are interdependent, violating the residual independence assumption of regression methods such as Cox proportional hazards models (Lee and Wang 2003). Second, latent risks for different outcomes (DDKT, LDKT, and mortality on the waiting list, mortality and graft failure post-transplantation) are likely interdependent. Third, if transplant candidates obtain a transplant and subsequently experience graft failure, they frequently return to the waiting list to seek an additional transplant, meaning that observations are not independent from one another. Fourth, hazards for these outcomes, and racial inequalities therein, are highly time-dependent, violating the proportional hazards assumption of many commonly used survival analysis models. Most importantly, kidney transplantation occurs in a dynamic system in which one’s transplantation prospects depend not just on one’s characteristics, but on the number and characteristics of other transplant candidates, deceased kidney donors, and potential living kidney donors in one’s social network.

Rather than a mere list of analytical difficulties, however, these characteristics of the KT system provide an opportunity. Crucially, the process by which deceased donors and transplant candidates are linked is publicly available and algorithmic in nature, meaning that it can be computationally reproduced. While this advantage does not apply to other key outcomes (LDKT, mortality, graft failure, and kidney offer acceptance), these outcomes can be simply analyzed in a manner which captures group-specific risks of different outcomes at each stage of the KT process. To account for these
characteristics of the KT system, simulation-based methods will be used in this study. The goals of this analysis are twofold: first, to reproduce the basic functioning of the KT system; and second, to understand the degree to which different proximate determinants of KT outcomes are primarily responsible for racial inequalities in the KT system.

Simulation Methods and the Counterfactual Model of Causality

Simulation techniques are advantageous and feasible for this study for a number of reasons. First, the different potential outcomes of participation in the KT system (DDKTs, LDKTs, waitlist mortality, graft failure, and post-transplant mortality) are interdependent for individuals over time and between individuals cross-sectionally. No standard regression techniques of which the author is aware are appropriate for these sorts of process.

Second, although microsimulation is frequently critiqued for its dependence on model assumptions (Ruggles 1993), in the case of KT the rules of the game are unusually well-known. The number of deceased donor kidneys is known, as is the number of candidates at all time periods and the process by which kidneys are offered to transplant candidates. Although the exact process by which candidates obtain LDKTs, accept DDKT offers, die, and reject their organs post-transplantation is not as well understood, the group-specific hazards of these outcomes may be incorporated into the simulation using life table or other techniques.

The approach to simulation taken in this analysis is motivated by the counterfactual causality tradition (Heckman 2005; Holland 1986; Morgan and Winship 2007). In brief, the crucial intuition behind the counterfactual approach is to consider all observations as having two or more potential outcome states in response to an exogenous

15 However, note that this is equally true of nearly all statistical analyses.
‘treatment,’ as in an experiment. The effect in such a framework is the gap between the outcome state of an observed case under hypothetical treatment and control assignment statuses. Following Holland’s (1986) exposition, the causal effect of interest in the dichotomous predictor case amounts to $Y_t - Y_c$, where $Y_t$ is the observed outcome under the ‘treatment’ condition and $Y_c$ is the observed outcome under the ‘control’ condition of the predictor variable of interest (say, an intervention).

While typical counterfactually motivated methods are inappropriate for this topic, counterfactual thinking suggests a solution to understanding the contribution of a variety of factors to racial inequalities in the KT system. The key is to think of the KT system as such – there are a number of determinants of KT outcomes with differential distributions by race. When seeking to understand the contributions of these determinants to racial inequalities in the KT system, the system will be simulated under a baseline (‘control’) condition as well as a series of counterfactual (‘treatment’) simulations wherein the distribution of a determinant of KT outcomes is equalized. This procedure will be conducted for the following seven determinants: place of residence, probabilities of DDKT offer acceptance, mortality hazards, living donor hazards, graft failure hazards, PRA, and ABO/HLA values. When more than one variable is redistributed (as in ABO/HLA, in which ABO type and six HLA alleles are involved), these will be redistributed jointly. When a hazard or probability is the property of interest, these will be the time- and group-specific hazard estimated for candidates (the estimation procedure is described below). Place of residence is measured as the OPO within which candidates are nested in the KT system.

**The Kidney Transplantation Simulation**
The design of the simulation employed in this study is depicted in Figure 2. First, the initial waiting list is established. All transplant candidates who were on the waiting list on July 1, 2000 are included on the baseline waiting list. Once the waiting list is established for this date, the dynamics thereof are simulated in 90-day increments through January 1, 2010.

Second, periodically new persons join the waitlist. Each person who joined the waiting list for the first time since July 1, 2000 is added to the waiting list in the 90-day window in which they did so. Third, once on the waiting list one may exit it in one of three ways. To begin, one may die. Hazards of waiting list mortality are estimated separately for each race- and education-specific group for each 90-day time period through approximately the first three years of waiting list time using life table techniques. Hazards thereof for the fourth and fifth years on the waiting list are estimated by calculating the race- and education-specific 90-day hazards pooled over those years of waiting list time. Finally, waiting list mortality hazards for time spent on the waitlist beyond five years are pooled together in the life table procedure. (Identical time period breakdowns are used in all subsequent hazard estimations and are not discussed further.)

Next, one may exit the waiting list by obtaining an LDKT, the risk for which is estimated using a procedure identical to that just described for waiting list mortality events. Those simulated to die are eliminated from further consideration in the simulation, whereas

16 Although 90-day increments are somewhat arbitrary, given the computational intensity of this research design, a coarsening procedure was necessary in the interests of computationally feasibility.

17 Since hazards are modeled in 90-day increments, four such periods add up to only 360 days, not 365. ‘Year’ is used as a linguistically convenient term for 360 day periods for the duration of this paper. Years 3, 4, and ≥5 are analyzed jointly a) because similar hazards applied during these time spans and b) to ensure sufficient observations for stable estimates.
those simulated to obtain an LDKT are moved to the post-transplant stage of the simulation, as depicted in Figure 2.

Additionally, one may exit the waiting list by obtaining a DDKT. These events are simulated by reproducing the functioning of the kidney allocation system as described above. The priority rankings of each KT candidate for each kidney are converted to allocation scores in which higher values represent higher priorities. In the interests of simplicity, payback credit obligations and prior living donor statuses are not accounted for in this simulation. Additionally, there are a number of subnational variations in the allocation system which are not reproduced in this allocation simulation. Finally, the allocation algorithm here simulated was only initiated in 2003. As such, the results of this simulation may be interpreted as the causes of racial inequality in KT if the present national allocation system had been used since July 1, 2000.

The result of this procedure is a candidate-by-donor matrix of allocation priority scores. The rows of this matrix represent each of the transplant candidates simulated to be awaiting a transplant (those who have not yet died, received an LDKT, or a previous DDKT for this waiting list stint). The columns represent each of the DDKs which were transplanted during this 90-day time period. DDKs are sorted left-to-right in the order in which they were transplanted, and ‘offered’ sequentially to KT candidates in order of their priority scores among those who have been simulated to accept the offer if received.

Probabilities of acceptance are estimated as a function of KT candidate and donor characteristics as well as their ABO and HLA histocompatibilities. The regression coefficients from a logistic regression model of offer acceptance (in logit form) are multiplied by the relevant candidate and donor characteristics and candidate-donor
histocompatibilities and summed for each candidate-donor combination in that time period, then converted to predicted probabilities of offer acceptance. Predicted probabilities are then compared to the value of a random uniform variable to convert probabilities into outcomes. Once this procedure has been completed, the probability of HLA positive crossmatching is estimated as

\[ P(XM) = PRA \left( \frac{6 - M_{ik}}{6} \right) \]  

where XM is a positive crossmatch, PRA is the panel reactive antibody score for that patient, and M_{ik} is the number of HLA matches for that candidate-donor pair. The second term adjusts the PRA value proportionate to the proportion of non-equivalent HLA alleles for that candidate-donor combination because one cannot be presensitized to one’s own antigens. Transplant candidates simulated to be positively crossmatched to the donor are not awarded the transplant.

Among the candidates simulated to accept the transplant conditional on being offered and who are not simulated to be positively crossmatched with the donor, the kidney is awarded to the patient with the highest priority score for that kidney. This procedure is repeated for each DDK available during that period, and those candidates simulated to receive a DDKT through this procedure are moved to the post-transplant condition within the simulation.

Once one has received a transplant, one may exit the post-transplant condition through one of two ways. First, as before, one may die, in which case one is eliminated from the simulation. Hazards for post-transplant mortality are estimated using life table techniques on all person-time periods observed 7/1/2000 to 2/26/2010 among those who had obtained a kidney transplant, as described above. Second, one may experience graft
failure, wherein one’s body rejects the transplanted kidney. Once this has occurred, one may return to the kidney transplant waiting list or return to dialysis. The probability of re-waitlisting was estimated using logistic regression techniques (not shown), and post-transplant persons are, conditional on experiencing graft failure, returned to the waiting list if the value of a random uniform variable is less than the estimated probability of re-waitlisting.

This simulation is repeated for each of the counterfactual conditions described above – redistributing place of residence, probabilities of DDKT offer acceptance, mortality hazards, living donor hazards, graft failure hazards, PRA, and ABO/HLA values. The effects of these counterfactual conditions are then calculated as

$$\beta_{OC} = 100 \frac{(\bar{X}_{WB} - \bar{X}_{OB}) - (\bar{X}_{WC} - \bar{X}_{OC})}{(\bar{X}_{WB} - \bar{X}_{OB})}$$

where $\bar{X}_{WB}$ represents the mean outcome for whites in the baseline simulation; $\bar{X}_{OB}$ represents the mean outcome for another racial/ethnic group in the baseline simulation; $\bar{X}_{WC}$ represents the mean outcome for whites in the counterfactual condition C; and $\beta_{OC}$ may be interpreted as the percentage of the gap between group O and whites for this outcome ‘explained’ by equalizing the factor C. In other words, $\beta_{OC}$ is the percentage of the gap between this group and whites which would not be observed if there were no racial differences in the counterfactual variable C.

Since this method of effect calculation may be unfamiliar, some examples should prove helpful. Suppose that the place of residence resulted in an estimated effect of 50 for African Americans. This would indicate that 50% of the white-black differential in transplantation rates would be eliminated in the absence of residential segregation. Now, suppose that the effect were 150 – this would indicate that rates of transplantation are
higher for blacks in this condition than for whites, and that the counterfactual black-white gap (with a black advantage) is 50% as large as that estimated in the baseline simulation (with a white advantage). Finally, suppose that this effect were -50 – this would indicate that the white-black differential in transplantation was made 50% larger in this counterfactual condition compared to the baseline simulation results.

The next section proceeds as follows. First, the degree and nature of racial and ethnic inequality in the KT system will be explored descriptively. Second, the composition of the KT waiting list will be described. Third, racial differences in the proximate determinants of transplantation outcomes will be described. Fourth, the performance of the KT simulation will be assessed, and the estimated counterfactual effects described.

Results

Waiting List Composition

During this time period, 332,635 unique persons participated in the KT waiting list (Table 1). For all racial and ethnic groups, males are overrepresented compared to women. The age distribution is somewhat younger for African Americans than for members of other racial and ethnic groups. Racial differences in educational attainment, however, are reflected in the waiting list composition – whites and Asians have higher average educational attainments than do African Americans and Hispanics. Finally, moderate racial differences in PRA are observed. On average, Asians have the lowest PRAs, followed by Whites and Hispanics, then African Americans. This last difference is substantial – the average African American PRA is nearly 50% higher than that for whites.
The Degree of Racial Inequality in the KT System

The next step of this analysis is to establish the degree of racial and ethnic inequalities present in the KT system. Viewed broadly, racial inequalities in the KT system may be created at two primary stages – first, racial differences in ESRD and seeking kidney transplants, and second, in the likelihood of obtaining a transplant conditional on seeking one. Both questions are crudely assessed in Table 2, which compares the distribution of racial categories in the U.S. population (measured using pooled American Community Survey microdata 2001-2009, provided by IPUMS-USA; Ruggles et al. 2010), the transplant waiting list (the distribution of race and ethnicity among everyone who has sought a KT between 2000 and 2/26/2010, measured using the UNOS STAR dataset), and the pool of persons obtaining a transplant (the distribution of race and ethnicity among everyone who has obtained a KT during this same time period). To the degree that racial distributions on the waiting list differs from the distribution in the population, this suggests racial differences in the ESRD/waitlisting process; to the degree that racial distributions in the transplant recipient pool differs from the distribution on the waiting list, this suggests racial differences in the transplantation process.¹⁸

The results of this exercise demonstrate that substantial racial inequalities occur at both stages of this process. Compared to whites, members of racial and ethnic minority groups are greatly overrepresented on the KT waiting list. For instance, African Americans are 2.23 times more likely than one would expect based on their population distribution to be found on the waiting list, and 2.89 times more likely to be on the KT waiting list than are whites based on their population distributions. While Hispanics’ and

¹⁸ Of course, this is a crude exercise. The racial distribution on the waiting list has evolved over time, so differences in the timing of waiting list entry could account for some of these differences. Nevertheless, this exercise is revealing of the degree of KT inequality by race/ethnicity in the transplant system.
Asians’ representations on the waiting list are more proportionate to their share of the population, the disproportionately low share of whites on the waiting list is a source of white-Hispanic and white-Asian inequality at this stage of the transplant process.

Similar inequalities are observed in transplantation outcomes comparing whites with members of racial and ethnic minority groups. Whites are approximately 12% more likely to be represented in the transplant recipient pool than would be expected based on their proportion on the KT waiting list, while members of other groups are underrepresented. Compared to whites, African Americans, Hispanics, Asians and Pacific Islanders, and members of other groups are respectively 23%, 17%, 24%, and 16% less likely to be represented in the transplant recipient pool than would be suggested by their share of the KT waiting list.

**Trends in Racial Inequalities in Kidney Transplant Outcomes**

Racial inequalities in outcomes once on the KT waitlist have changed over time. Figures 3 and 4 depict time trends in racial inequalities in kidney transplantation outcomes. Figure 3 depicts risk ratios of transplantation outcomes by spell for African American, Hispanic, Asian, and other groups relative to whites by year of waiting list entry. (Years of waiting list entry prior to 2000 are grouped together in the ‘1999’ category.) Ratios greater than 1 would therefore indicate an advantage of the depicted group in that outcome compared to whites; ratios equal to 1 would indicate equal prospects to those of whites; and ratios less than 1 indicate disadvantages compared to whites.

As can be seen, white advantages in transplantation outcomes compared to other groups have grown over time, although this could reflect differences due to censoring.
rather than eventual outcomes. For instance, African Americans experienced roughly equal rates of DDKTs compared to whites through the 2004 waiting list cohort, but African American members of the 2009 cohort were only about 75% as likely as whites to have obtained a DDKT by the end of the present data collection. Similar trends in DDKT inequalities are observed for members of other racial and ethnic groups. Even starker, however, are racial differences in the proportion obtaining LDKTs before censoring. African Americans in the 2000-2004 waiting list cohorts are only about half as likely as similar whites to have obtained an LDKT, and this ratio decreases in subsequent years. Although racial differences in this outcome are less severe for members of other racial and ethnic minority groups, the inequalities have similarly increased with time. LDKTs are therefore a major potential proximate determinant of overall racial inequalities in the KT system.

Figure 4 depicts identically calculated racial disparities in mortality and graft failure over time. The results here are somewhat more complex than those for transplantation outcomes. First, African Americans are substantially more likely to die or experience graft failure while in the KT system than are whites, although in more recent cohorts this inequality has been ameliorated. Hispanics of all cohorts experience mortality at slightly higher rates than whites, but their rates of graft failure have been lower in recent years than whites’. Asian patients experience mortality at roughly the same rates as whites and graft failure at substantially lower rates. Members of other racial and ethnic groups, finally, are subject to higher rates of mortality than are whites, and approximately equal rates of graft failure (though the latter differences have varied substantially by waiting list cohort). In summary, racial and ethnic differences in
mortality and graft failure could play substantial roles in explaining overall KT system inequality, particularly for African Americans. In contrast, the lower graft failure rates of Hispanics and Asians could provide a source of advantage in the overall KT system.

**Racial Differences in Offer Acceptance**

Table 3 presents selected results from an analysis of DDKT offer acceptance rates based on a dataset of all DDKT offers made by UNOS after July 1, 2000 through 2/26/2010. A series of logistic regression models were estimated examining the probability of offer acceptance conditional on candidate demographic characteristics, candidate-donor biological match, candidate health, and donor characteristics. All of this information is available to transplant candidates and their doctors when deciding whether to accept a DDKT offer from UNOS.

Model 1 in Table 3 presents the coefficients (in odds’ ratio form) from a model predicting offer acceptance based on candidate demographic characteristics only. Net of other demographic controls, the results show that racial and ethnic minorities are more likely to accept a DDKT offer than are whites.

Models 2-4 in Table 3 examine this relationship with additional controls. Model 2 adjusts the model for candidate-donor HLA and ABO histocompatibility. Consistent with the nephrology’s emphasis on histocompatibility, HLA and ABO compatibility are highly predictive of DDKT offer acceptance. Compared to none, two HLA-DR or HLA-B matches between the donor and candidate are associated with more than 4.5 times the odds of acceptance. Consistent with the general finding in nephrology that HLA-A

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19 These data are not part of the standard UNOS STAR file. The author thanks UNOS for generously sharing this information.

20 Standard errors and significance tests are not shown because this data is a census of all offers made during this time period, and therefore there is no population to generalize to.
matching is the least important HLA consideration, the effect of perfect matching at this locus is less than half of that for \textit{HLA-B} and \textit{DR}. \textit{ABO} similarity between the donor and candidate was also predictive of DDKT offer acceptance – compared to identical matches (the most desirable outcome), donors whose blood is merely histocompatible with the candidate had only .64 times the odds of acceptance.

Additionally, controlling for biological similarity increases the effects of race and ethnicity on the odds of offer acceptance. Net of these and other demographic controls, African Americans have 1.51 times the odds of acceptance compared to whites. Comparable figures for Hispanics, Asians, and others are 1.26, 1.64, and 1.38, respectively. Additional controls for candidate health and donor characteristics do not appreciably ameliorate these relationships.

\textbf{Simulation Results}

\textbf{Baseline Simulation Validation}

Table 4 presents the results of the simulation compared to the observed distribution of outcomes, and Table 5 presents the results of the counterfactual exercise. The simulated figures in Table 4 represent the mean outcomes of a series of 100 simulations of the baseline condition on ten different imputed datasets of the UNOS data (with ten such simulations apiece), with each such simulation estimated on a randomly selected 20% subset of the UNOS dataset of KT candidates and DDKs\textsuperscript{21}. Table 4 presents the proportion of waitlist and post-transplant spells resulting in any transplant, DDKT, LDKT, waitlist mortality, graft failure, and post-transplant mortality observed and

\textsuperscript{21} Due to the matrix-based nature of the simulation, this 20% subsetting was conducted in the interests of computational feasibility. Simulating the full system requires more than 50gb of memory and extremely long computational times. The computational time required to simulate subsets of the data is substantially less.
simulated and the percentage by which the simulation results differ from the observed data. A 90% simulation interval, reflecting differences in typical outcomes across the 100 baseline simulations spread evenly across the ten imputed datasets, is also presented for the simulated proportions. Finally, the ratio of outcomes between whites and other races and ethnic groups is also presented.

The baseline simulation results broadly capture racial differences in outcomes, albeit imperfectly. Overall whites are more likely to obtain any transplant, with whites slightly less likely to obtain a DDKT than are blacks and Hispanics, and substantially more likely to obtain an LDKT compared to other racial and ethnic groups. As in the observed data, whites are less likely than blacks and others to experience waitlist mortality, with Hispanics and Asians less likely than whites to experience this outcome. After obtaining a transplant, whites are less likely than blacks and others to experience graft failure, while Hispanics and Asians have the lowest rates of this outcome. Finally, whites, blacks, and others experience post-transplant mortality at the highest rates, while Hispanics and Asians enjoy lower rates of this eventuality.

The simulation model does not perfectly capture all of these dynamics. Rates of DDKTs for all groups are somewhat underestimated by the simulation model. Rates of LDKTs are overestimated for whites and underestimated for Asians and others, while rates of waitlist mortality are overestimated for whites, Hispanics, and Asians. Post-transplantation, the model underestimates rates of graft failure for blacks, and underestimates rates of post-transplant mortality for blacks and others. Improving the predictive validity of this model is a priority for future research on this matter.
However, the model does largely capture racial differences in all of these outcomes. Concerning the primary outcome of interest—obtaining a kidney transplant—the model very closely approximates racial differences in this outcome with the exception of the Hispanic-white comparison, wherein the inequality is somewhat overstated. Due to the underestimation of rates of DDKT for whites in this model, racial differences in this outcome are also somewhat exaggerated. Similarly, discrepancies between the model results and the simulation also somewhat exaggerate racial disparities in LDKT and post-transplant mortality. However, differences in waitlist mortality and graft failure closely approximate observed racial and ethnic differences in these outcomes. Overall, while imperfect, the contours of racial inequality in the simulation and the observed data are very similar.

Counterfactual Simulation Effects

With these caveats in mind, the results of the counterfactual simulation exercise are useful for identifying the major determinants of racial inequality in the KT system. Broadly speaking, racial differences in LDKT rates, genetics, and place of residence explain the bulk of racial inequality in the KT system.

Equalizing the distribution of ABO and HLA by race results in a 41%, 75%, and 36% reduction in transplant inequality for blacks, Hispanics, and Asians respectively compared to whites, suggesting that racial distributional differences in these important determinants of racial inequalities in the KT system. Similarly, equalizing LDKT hazards in the simulation results in a 108, 155, and 79% reduction in racial differences in transplantation outcomes for blacks, Hispanics, and Asians respectively, such that if LDKT hazards were equalized blacks and Hispanics would have higher rates of
transplantation overall. Finally, place of residence plays an important role in this system, as redistributing this characteristic results in a 13% increase, 12% increase, and 10% decrease in inequality in transplant outcomes compared to whites for blacks, Hispanics, and Asians respectively. This suggests that place of residence is actually a source of advantage for Asians, while serving as a mechanism of white advantage compared to Hispanics and blacks. Finally, equalizing PRA scores across members of different racial and ethnic groups results in a 14% decrease, 142% increase, and 6% decrease in inequality compared to whites for blacks, Asians, and Hispanics respectively.

In summary, racial differences in LDKTs are primarily responsible for racial differences in transplantation outcomes overall, and racial differences in the distribution of ABO and HLA genes play a substantial role in the current allocation system as well. Finally, differences in area of residence explains a substantial proportion of the white advantage in transplantation vis-à-vis Hispanics and Asians on the KT waiting list, and racial and ethnic differences in PRA are a small source of white advantage compared to blacks and Asians and a significant source of advantage for Hispanics.

**Discussion**

Any system which allocates resources to participants on the basis of individual characteristics will produce group differences in outcomes to the degree that groups differ in those characteristics. In the case of kidney transplantation, organs for transplantation are obtained from one of two types of donors – living and deceased. One’s odds of obtaining a living donor transplant are strongly associated with race and ethnicity, and accordingly racial differences in transplantation outcomes are substantially influenced by racial differences in rates of LDKT. Furthermore, one’s chances of obtaining a deceased
donor kidney transplant are primarily structured by geography and genetics. These factors substantially explain racial differences in kidney transplant outcomes as well. Finally, racial and ethnic differences in PRA scores explain a substantial degree of racial inequality in the KT system for Hispanics and whites, while other investigated variables play relatively minor roles.

In modern societies most limited resources are allocated to those who seek them according to a set of criteria developed and implemented by institutional actors. For instance, enrollment in competitive universities is allocated in part on the basis of test scores, high school grades, writing ability, and life experiences, and racial differences in these factors helps to explain racial differences in enrollment at prestigious schools. These factors are selected in part because they are considered to be efficient use of limited space on the theory that those with stronger academic performance will better benefit from additional schooling and raise the quality of education for all at the university. However, universities frequently recognize that opportunities to develop strong academic skills and have useful life experiences are stratified by race and class, and accordingly allocate these positions in part on the basis of these factors.

Those who establish the rules by which to allocate DDKTs are faced with a similar task. There are not enough DDKs to provide transplants for all who seek them. Therefore UNOS allocates kidneys for transplant to candidates on the basis of a set of criteria thought to balance efficiency (seeking to get the maximum population benefit from transplantation) with equity (seeking to ensure equal access to this treatment option to all strata of society). The trouble is that these two goals are frequently contradictory. While allocating kidneys locally ensures that transportation times are minimized and
organs are better preserved, residential stratification by race in combination with geographic variability in deceased donor kidney availability means that members of different races vary in their access to DDKTs. Similarly, family and social network structure, characteristics, and dynamics are substantially associated with race and ethnicity. For unknown reasons these factors produce racial differences in rates of LDKTs. Finally, in the presence of racial distributional differences in ABO and HLA, being a racial minority itself is a source of disadvantage. While the incorporation of histocompatibility criteria into the kidney allocation algorithm is well justified from an efficiency perspective, these efficiency gains come at the cost of inequitable outcomes by race.

These findings highlight the difficulty of achieving racial equity in a racialized social system more generally. Many population processes are beyond the control of any institution. UNOS cannot influence where transplant candidates live, whether their family and friends donate kidneys, or the mating patterns of the population. Yet they do establish the rules by which kidneys are allocated to those who seek them for transplantation. By selecting the criteria by which these are allocated, UNOS in large part determines the nature and causes of the inequalities which will result, in combination with the behaviors of doctors, donors, and patients within this framework.

While the consequences of allocation decisions are constrained by key immunological and biological realities, the balance which UNOS strikes between efficiency and equity is fundamentally a political decision to which there is no right answer. Periodically UNOS has radically altered the allocation system for kidneys,
responding to concerns about racial inequalities in access and to changing technological conditions which structure the effects on efficiency of prioritizing equity.

These conditions will continue to change. For the present, however, it is clear that a number of steps could be taken to ameliorate racial inequalities in the transplantation system. First, research should continue on the causes of racial disparities in LDKTs and possible interventions to ethically ameliorate them. Potential living donors may fail to donate for a large number of reasons, including insufficient histocompatibility with the intended recipient, poor health, the willingness of the candidate to accept an LDKT, and so on. The factors which produce racial disparities in LDKT should be identified with careful research, whereupon interventions to promote LDKT among groups with disproportionately low rates thereof should be designed and implemented.

Second, the role of geography in the UNOS DDKT allocation system should be revisited. This has some precedent - in 1998, then-Department of Health and Human Services Secretary Donna Shalala proposed a set of changes to the policies governing organ allocation in the United States, which came to be known as the Final Rule. Among other things, these changes would have required the elimination of the geographic factor in the allocation process, instead creating a single national waitlist. Certain regions benefit disproportionately from a geographically-based system because they have high rates of organ donations relative to demand, resulting in large geographic disparities in rates of DDKT. The political and medical leaders within these regions led the charge to defeat the national list, in which they succeeded when a version of the Final Rule lacking this provision was eventually instituted. This political decision should be revisited in light
of the role that geographic apportionment of DDKTs plays in the production of racial disparities in transplantation outcomes.

Third, research should continue on immunosuppression and related technologies which can facilitate successful transplantation between non-histocompatible donors and recipients. Should this technology advance sufficiently, it is possible that, like HLA-A and –B before it, the role of HLA-DR histocompatibility in the DDKT allocation system could be reduced or eliminated. Though likely more difficult, it is possible that the role of ABO in the allocation system could eventually be reduced or eliminated, as well.

This study improves upon previous research on racial disparities in KT by treating KT as a system rather than a collection of individual outcomes. This theoretical and methodological improvement highlights the degree to which LDKT rates, genetic distributions, and geographic distributions mediate racial disparities in KT outcomes. However, this study is subject to a number of important limitations. First, the fit of the model to the observed outcomes is imperfect. Future research on this topic should seek to improve the predictive validity of this or related models. Second, the hazards of LDKT, mortality, and graft failure employed by this model are crude, predicting outcomes stratified only by race-education intersections. Future research should refine these estimates to adjust post-transplant outcomes by transplant characteristics (e.g., type, histocompatibility) and additional individual and institutional characteristics. However, the advantage of the life table methodology employed in this study is the freedom from distributional assumptions concerning latent individual hazards. The variety of semi-parametric competing risk models which were previously fit to this data (not shown) failed to produce adequate fit and were discarded. Methods capable of adequately
analyzing hazards in the KT system while accounting for competing risks of exit should be developed to improve understanding of the full set of factors contributing to group differences in LDKT, graft failure, and mortality.

Additionally, the estimates obtained for the effects of the proximate determinants of transplantation outcomes are ‘bivariate’ in the sense that only one determinant is equalized in each simulated counterfactual. Future research should measure the effects of each counterfactual while accounting for the remaining factors. Furthermore and perhaps more importantly, the estimation strategy employed in this study assumes a ceteris paribus relationship between these counterfactuals and the outcomes observed. For instance, the effect of place of residence on transplantation outcomes is assumed to be unrelated to LDKT hazards, which may not be the case. Additionally, because actors in the KT system may adjust their behaviors to account for changing conditions, it is unlikely that the present estimates are precisely the differences in outcomes which would be observed under the estimated counterfactuals. Future research should investigate how changing conditions in the KT system affect key behaviors such as rates of LDKT, re-waitlisting following graft failure, and DDKT offer acceptance.

Finally, stating that racial differences in LDKT explain racial differences in KT overall raises the obvious question of why members of different racial and ethnic groups vary in LDKT outcomes. LDKTs primarily come from family and friends of transplant candidates. Although some progress has been made in the medical literature on this topic, future research should investigate the distribution of suitable living donor availability by race and the processes by which donor availability results in LDKTs, and how these processes may contribute to racial differences therein.
Conclusion

This paper reports on a simulation study on the major determinants of racial inequalities in kidney transplants. Crucially, unlike previous research this study accounts for the systemic nature of the allocative system and incorporating information on the kidney transplant allocation algorithm alongside group differences in hazards of mortality, graft failure, PRA, and living donor kidney transplants, and deceased donor kidney transplant offer acceptance rates. The findings identify rates of living donor kidney transplants, distributions of blood type and HLA genes, PRA, and place of residence as major mediators of racial disparities in kidney transplantation outcomes.

To date, research on racial disparities in health has largely focused on major markers of overall health, self-reported health status, and all-cause mortality. While valuable, this literature has been hampered by the generalizations necessary to speak of health outcomes as though they had uniformly common causes. By studying a particular and important cause of ill health and health inequality and discussing the sociological issues raised therein, this study advances the literature on health inequality.
References


Gordon, E. J. 2001. ""They don't have to suffer for me": Why dialysis patients refuse offers of living donor kidneys." *Medical Anthropology Quarterly* 15:245-267.


Tables and Figures

Figure 2.1: Deceased Donor Kidney Allocation National Algorithm, 2003-Present

NOTE: This figure represents the national kidney allocation priority algorithm since 2003. This does not represent local variations in allocation policy. Read left to right, each subsequent level reflects priorities within categories of the columns to the left, and categories closer to the top (for the first three levels) are higher priorities.
Figure 2.2: Simulation Design

*: Simulated using Life Tables
†: Timing determined using Observed Event Date
‡: Simulated using UNOS Kidney Allocation Algorithm and Offer Acceptance Model
Figure 2.3: Trends in Racial Inequality in Transplantation Outcomes, 1990-2009

NOTE: Figures plotted are the risk ratio of the indicated racial group to that of whites for the outcome in question. Years indicate the year individuals joined the kidney transplant waitlist. Those joining the waitlist in 1990 or earlier are collapsed into the first (1999) category. Those joining the waiting list in 2010 are omitted.
Figure 2.4: Trends in Racial Inequality in Mortality and Graft Failure Outcomes, 2000-2009

NOTE: Figures plotted are the risk ratio of the indicated racial group to that of whites for the outcome in question. Years indicate the year individuals joined the kidney transplant waitlist. Those joining the waitlist in 1990 or earlier are collapsed into the first (1999) category. Those joining in 2010 are omitted.
Table 2.1: Descriptive Statistics, Kidney Transplant Waitlist, 2000-2010

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<th>Hispanic (N=47,031)</th>
<th>Asian (N=17,010)</th>
<th>Other (N=7,038)</th>
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<td></td>
<td>Mean/% SD</td>
<td>Mean/% SD</td>
<td>Mean/% SD</td>
<td>Mean/% SD</td>
<td>Mean/% SD</td>
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<td>PRA</td>
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<td>21.18 (33.53)</td>
<td>14.31 (28.71)</td>
<td>12.74 (27.03)</td>
<td>12.89 (27.23)</td>
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</tbody>
</table>

NOTE: Values for demographic categories are percentages; values for PRA are means and standard deviations, as indicated. Data on kidney transplant waitlist composition from 7/1/2000 through 2/26/2010. SOURCE: UNOS STAR files.
### Table 2.2: Racial Inequality in Transplantation

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<th>Racial Inequality Comparisons</th>
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NOTE: ‘ACS’ stands for American Community Survey, and reflects the individually weighted racial percentage distribution in the 2001-2009 American Community Survey data, provided by IPUMS-USA. The ‘Waitlist’ column is the percentage distribution of racial categories for persons entering the UNOS kidney transplant waitlist 2000-2010. The ‘Transplant’ column is the racial percentage distribution among those who received any kidney transplant in the 2000-2010 waitlist cohorts. In the racial inequality comparisons, the ‘Ratio’ column is the ratio of the percentage makeup of the racial/ethnic group in question in the first listed category compared to the second, and the ‘Vs. Whites’ column is the ratio of the ratio figure for that race compared to the same ratio for whites.
### Table 2.3: Deceased Donor Kidney Allocation Offer Acceptance Model, 2000-2010

<table>
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<tr>
<th></th>
<th>(1) Demographics</th>
<th>(2) + Candidate-Donor Match</th>
<th>(3) + Candidate Health</th>
<th>(4) + Donor Characteristic</th>
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NOTE: Observations in this analysis are each deceased donor kidney offer event. Coefficients are presented as odds ratios. Standard errors and statistical significance tests are omitted because these results are based on a census of deceased donor kidney transplant
offers 7/1/2000 through 2/26/2010. Smaller sample sizes in columns (3) and (4) reflect observation omissions due to listwise deletion for missing data.
Table 2.4: Observed and Simulated Outcomes by Race

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<th>Simulation</th>
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<tr>
<td>DDKT</td>
<td>Black</td>
<td>0.250</td>
<td>1.032</td>
</tr>
<tr>
<td></td>
<td>Hispanic</td>
<td>0.246</td>
<td>1.015</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>0.231</td>
<td>0.954</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>0.250</td>
<td>1.032</td>
</tr>
<tr>
<td></td>
<td>White</td>
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</tr>
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<td>Black</td>
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<td>0.462</td>
</tr>
<tr>
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<tr>
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<td>Hispanic</td>
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</tr>
<tr>
<td></td>
<td>Asian</td>
<td>0.158</td>
<td>0.881</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>0.219</td>
<td>1.221</td>
</tr>
<tr>
<td>Post-Transplant</td>
<td>White</td>
<td>0.190</td>
<td>--</td>
</tr>
<tr>
<td>Graft Failure</td>
<td>Black</td>
<td>0.262</td>
<td>1.379</td>
</tr>
<tr>
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<td>Hispanic</td>
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<tr>
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<td>Asian</td>
<td>0.139</td>
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<tr>
<td></td>
<td>Other</td>
<td>0.217</td>
<td>1.143</td>
</tr>
<tr>
<td></td>
<td>White</td>
<td>0.120</td>
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<tr>
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<td>0.115</td>
<td>0.957</td>
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<td>Asian</td>
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</tr>
<tr>
<td></td>
<td>Other</td>
<td>0.123</td>
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</tr>
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</table>
NOTE: DDKT stands for deceased donor kidney transplant; LDKT stands for living donor kidney transplant. Percentage difference is the percentage by which the simulated proportions are different from the observed proportions.
Table 2.5: Counterfactual Effects

<table>
<thead>
<tr>
<th>Race</th>
<th>Counterfactual</th>
<th>Any Kidney Transplant Proportion (90% Interval)</th>
<th>% Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>None (Baseline)</td>
<td>0.354 (0.350,0.358)</td>
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<tr>
<td></td>
<td>Genetics</td>
<td>0.342 (0.339,0.347)</td>
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</tr>
<tr>
<td></td>
<td>Graft Failure</td>
<td>0.355 (0.351,0.359)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Living Donor</td>
<td>0.331 (0.327,0.334)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Mortality</td>
<td>0.355 (0.351,0.358)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Offer Acceptance</td>
<td>0.354 (0.350,0.358)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Residence</td>
<td>0.355 (0.352,0.360)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>PRA</td>
<td>0.355 (0.352,0.358)</td>
<td>--</td>
</tr>
<tr>
<td>Black</td>
<td>None (Baseline)</td>
<td>0.288 (0.282,0.296)</td>
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</tr>
<tr>
<td></td>
<td>Genetics</td>
<td>0.303 (0.298,0.311)</td>
<td>40.7</td>
</tr>
<tr>
<td></td>
<td>Graft Failure</td>
<td>0.290 (0.283,0.298)</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Living Donor</td>
<td>0.336 (0.331,0.341)</td>
<td>108.0</td>
</tr>
<tr>
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<td>Mortality</td>
<td>0.289 (0.284,0.296)</td>
<td>0.4</td>
</tr>
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<td></td>
<td>Offer Acceptance</td>
<td>0.288 (0.282,0.296)</td>
<td>0.2</td>
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<td>Residence</td>
<td>0.281 (0.273,0.292)</td>
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<tr>
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<td>PRA</td>
<td>0.298 (0.295,0.301)</td>
<td>14.3</td>
</tr>
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<td>0.335 (0.317,0.344)</td>
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<tr>
<td></td>
<td>Genetics</td>
<td>0.338 (0.323,0.350)</td>
<td>75.1</td>
</tr>
<tr>
<td></td>
<td>Graft Failure</td>
<td>0.335 (0.321,0.345)</td>
<td>-1.4</td>
</tr>
<tr>
<td></td>
<td>Living Donor</td>
<td>0.341 (0.326,0.350)</td>
<td>154.5</td>
</tr>
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<td>0.0</td>
</tr>
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<td></td>
<td>Offer Acceptance</td>
<td>0.335 (0.317,0.344)</td>
<td>-0.4</td>
</tr>
<tr>
<td></td>
<td>Residence</td>
<td>0.334 (0.311,0.348)</td>
<td>-11.7</td>
</tr>
<tr>
<td></td>
<td>PRA</td>
<td>0.309 (0.304,0.314)</td>
<td>-141.9</td>
</tr>
<tr>
<td>Asian</td>
<td>None (Baseline)</td>
<td>0.278 (0.263,0.290)</td>
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<tr>
<td></td>
<td>Genetics</td>
<td>0.294 (0.281,0.306)</td>
<td>35.5</td>
</tr>
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<td></td>
<td>Graft Failure</td>
<td>0.279 (0.267,0.293)</td>
<td>0.1</td>
</tr>
<tr>
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<td>Living Donor</td>
<td>0.315 (0.302,0.329)</td>
<td>78.9</td>
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<tr>
<td></td>
<td>Mortality</td>
<td>0.278 (0.265,0.291)</td>
<td>-2.2</td>
</tr>
<tr>
<td></td>
<td>Offer Acceptance</td>
<td>0.278 (0.263,0.29)</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Residence</td>
<td>0.287 (0.274,0.301)</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>PRA</td>
<td>0.283 (0.270,0.293)</td>
<td>5.6</td>
</tr>
<tr>
<td>Other</td>
<td>None (Baseline)</td>
<td>0.327 (0.309,0.344)</td>
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</tr>
<tr>
<td></td>
<td>Genetics</td>
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<td>67.9</td>
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<tr>
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<td>Graft Failure</td>
<td>0.333 (0.316,0.352)</td>
<td>20.7</td>
</tr>
<tr>
<td></td>
<td>Living Donor</td>
<td>0.359 (0.342,0.378)</td>
<td>205.6</td>
</tr>
<tr>
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<td>Mortality</td>
<td>0.327 (0.311,0.344)</td>
<td>-3.4</td>
</tr>
<tr>
<td></td>
<td>Offer Acceptance</td>
<td>0.326 (0.308,0.344)</td>
<td>-3.0</td>
</tr>
<tr>
<td></td>
<td>Residence</td>
<td>0.305 (0.278,0.329)</td>
<td>-84.8</td>
</tr>
<tr>
<td></td>
<td>PRA</td>
<td>0.312 (0.301,0.329)</td>
<td>-55.4</td>
</tr>
</tbody>
</table>

NOTE: ‘% Effect’ columns are the percentage of the gap in outcomes between the race in question and whites eliminated in the counterfactual baseline compared to the baseline simulation.
Chapter Three: The Determinants of Educational Inequality in the Kidney Transplantation System

Introduction

A great deal of research in the social sciences, medicine, and public health is concerned with understanding the contours, causes, and consequences of the socioeconomic “gradient” in health outcomes in modern societies. Social conditions generally are often framed as “fundamental causes” of health outcomes (Link and Phelan 1995) because of their role in structuring access to resources and exposures which influence health outcomes. While much research has addressed socioeconomic disparities in mortality and many major causes of ill health, outside of the medical literature relatively little attention has been paid in this literature to kidney disease and kidney transplantation (but see Shoham et al. 2008). To maintain the field’s rapid progress (e.g., Harris 2010), research should increasingly investigate specific causes of ill-health and mortality to better understand the diversity of mechanisms linking socioeconomic status (SES) to differences in health and mortality. This is particularly important in light of evidence that the association of SES with different causes of death varies widely (e.g., Smith 2003).

Chronic kidney disease and end-stage renal disease pose a substantial and growing threat to population health, and are a site of significant racial, ethnic, gender, and socioeconomic disparities in morbidity. Focusing on those with end-stage renal disease (in which kidneys fail permanently), this is particularly confounding because, in the
United States, the Medicare End-Stage Renal Disease (ESRD) program provides insurance coverage to nearly all patients with ESRD, covering the costs of dialysis and all initial costs of transplantation, which is the preferred treatment modality. Although there are social differences in the process of medical approval for kidney transplantation (Epstein et al. 2000), once on the kidney transplant waiting list there should be no major financial constraints on one’s access to kidney transplantation. Despite this nearly universal insurance coverage for treatment of ESRD, however, socioeconomic disparities persist in the kidney transplantation system. The objective of this article is to assess the degree and proximate determinants of these socioeconomic disparities.

This goal is especially feasible in light of the high quality data available on the kidney transplantation system in the U.S. The United Network for Organ Sharing (UNOS), which administers the transplantation system under the aegis of the Department of Health and Human Services (DHHS), maintains a database of characteristics and outcomes of all kidney transplant candidates, recipients, and donors in the U.S. since October 1987. Furthermore, the rules by which deceased donor kidneys (DDKs) are allocated to transplant candidates are known and analytically reproducible. As such, the basic functioning of the kidney transplant system may be analytically reproduced and manipulated to better understand the major causes of socioeconomic inequalities in this important arena of health care and social inequalities. This analysis improves on previous analyses of similar questions by modeling the kidney transplant system in a manner which accounts for the interdependency of individual outcomes. By manipulating the

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22 However, if one pursues a living donor kidney transplant, one’s potential donors may incur substantial costs since in most states the foregone wages and discomfort of living donors is not compensated. Furthermore, it may be that, given that Medicare covers only three years of immunosuppressant therapy, the future costs of pursuing transplantation may be viewed to be prohibitive.
distribution of major determinants of kidney transplantation outcomes, this analysis finds that educational differentials in kidney transplant outcomes are strongly influenced by group differences in place of residence, genetic distributions, mortality hazards, graft failure hazards, and odds of obtaining a living donor kidney transplant (LDKT).

The Kidney Transplant System

Between 1988 and 2007, more than 420,000 organ transplants were performed in the United States with high and steadily improving rates of success. This is more impressive when one considers that the first effective immunosuppressant drug, cyclosporine, was not approved by the FDA until 1984. In the last thirty years, organ transplantation has shifted from an experimental and very risky procedure to become the therapy of choice for a range of ailments, resulting in numerous improved and extended lives.

Since 1984, in the United States organ allocation decisions have been entrusted the United Network for Organ Sharing (UNOS) by the U.S. government, which has done so by dividing the task among 11 subsidiary administrative regions. Within these regions subsidiary organizations known as Organ Procurement Organizations (OPOs) collect and allocate organs for transplantation according to national rules, with local variations. Using these administrative subdivisions, UNOS allocates organs guided by two principles: efficiency and justice. Efficiency means that they endeavor to save as many lives as possible by matching donated organs to those who are likely to best benefit from them. Justice means that this should be done in a manner broadly perceived to be fair to the individuals awaiting organs. The exact process by which organs are awarded to individuals who need them has changed over the years (and varies by organ) in an
attempt to better balance these two principles, and has for some time been implemented by a computer system which maximizes some function of medical, biological, and geographic factors to make this decision.

**Human Immunology and Kidney Transplantation**

The kidney allocation system is constructed at the intersection of medical and political considerations in UNOS’s attempt to balance the efficiency and equity imperatives of their mission. Three key factors in the allocation system – ABO, HLA, and PRA – are based on the rapid advances of the field of human immunology during the 20th century. These advances merit some brief discussion to provide context to the kidney allocation system (see Leffell et al. 1997; Morris 2001).

*Antigens and Histocompatibility.* The purpose of the immune system is to protect the host by attacking foreign cells, viruses, and particulates. The primary means by which this is done is through the presentation and scanning of antigens, proteins on the surface of cells which vary widely between members of the same species. Cells displaying antigens which do not contradict those presented by host cells are deemed ‘histocompatible’ and provoke no immune response; cells displaying contradictory antigens trigger an immune response.

In kidney transplantation two types of histocompatibility are crucial: ABO and HLA histocompatibility. *ABO* structures the combination of antigens presented on the outside of red blood cells. There are three alleles at this locus which produce one of four phenotypes through a codominance/recessive pattern: A, B, AB, and O. The A and B alleles are codominant and the O allele is recessive.
Leukocyte histocompatibility is similarly governed by the human leukocyte antigen (HLA) genes: among others, HLA-A, HLA-B, and HLA-DR. The considerable degree of polymorphism at these loci means that odds of histocompatibility with an unrelated individual are generally very small. As with ABO, there are a number of alleles at each locus which produce antigens which are ‘serologically equivalent’ and therefore histocompatible\textsuperscript{23}. In other words, two different cells displaying antigens governed by different alleles may be immunologically indistinguishable.

*Sensitization.* In addition to ABO and HLA histocompatibility, the transplant recipient’s set of antibodies play a major role in the immunology of kidney transplantation. If the recipient has previously been exposed to one of the donor’s non-histocompatible antigens, they may be presensitized to it, meaning that their body produces antibodies designed to target cells displaying these antigens. Presensitization occurs through one of three primary mechanisms: 1) pregnancy, 2) blood transfusions, and 3) previous transplants (Leffell et al. 1997). Immunological reactions to foreign cells to which the host is presensitized are far more rapid and severe than responses to cells to which they are not presensitized.

There are two common measures of immunological sensitization used in kidney transplantation. One, called the Panel Reactive Antibody (PRA) score, is a measure of the probability that one has produced antibodies to a random human’s antigens. Those with high PRA scores are among the most difficult to match to a suitable kidney. If one’s blood immediately reacts to a potential donor’s, this pair is said to be ‘positively

\textsuperscript{23} Although research on this topic is ongoing, the current UNOS list of HLA serological equivalencies, summarized in Appendix 3A to UNOS policy 3, approved in September 2007, is used as the authoritative list. This is available for inspection at [http://optn.transplant.hrsa.gov/policiesAndBylaws/policies.asp](http://optn.transplant.hrsa.gov/policiesAndBylaws/policies.asp). Accessed 8/21/2010.
crossmatched,” meaning that the candidate is presensitized to the donor’s antigens. In such cases the transplant is generally not conducted.

**The Kidney Allocation System**

Figure 1 depicts the current (as of 9/15/09) UNOS standard (high quality) cadaveric kidney allocation procedure for organ donors age 35 and older. Similar procedures are used for younger donors. This allocation formula does not depict subnational variation in allocative procedures due to space limitations. “Expanded criteria” donor (ECD, kidneys donated by those who are older or less healthy than those typically accepted) organs are allocated on a similar basis, but without prioritization of pediatric patients or high-PRA patients.

In the current national allocation system, transplant candidates’ prioritizations are organized into four tiers. In each tier, higher ranking in higher tiers (depicted on the left of Figure 1) take precedence over higher rankings in lower tiers. With some exceptions, one’s priority ranking fundamentally depends on the joint properties of each potential donor-candidate match.

In the present allocation system perfect HLA matches are given the highest priority as they are associated with superior post-transplant outcomes (Morris 2001). Second, those who have previously served as living kidney donors are given priority, followed by matches between candidates and donors between whose OPOs a debtor-creditor relationship has been previously established. Afterward geography is the primary determinant in the first tier, such that DDKs from a given OPO are allocated first to others in the OPO, followed by others in the same region, and finally based on national priority.
The second priority tier emphasizes ABO compatibility between the donor and candidate. Those with the same blood type are prioritized, followed by pairs involving candidates with a B blood type and donors with an O blood type. Finally, mere ABO compatibility is given the lowest priority. Candidate-donor pairs which are not ABO histocompatible are rarely awarded transplants.

The third priority tier ranks candidates based on their age and PRA. First, candidates in the highest PRA category (80-100%) are prioritized. Second, pediatric patients are prioritized over adults, and within these categories additional priority given to those with elevated PRA scores (21-79%). Finally, the fourth tier of the allocation algorithm distinguishes between otherwise similar patients. First, HLA-DR matches are awarded one point apiece\(^2\)\(^4\). Second, pediatric candidates are awarded priority, especially when the donor is younger than 35. Finally, conditional on these factors candidates are prioritized based on their waiting time such that one point is awarded for each year on the waitlist, plus an OPO-specific waiting time tiebreaker.

**Socioeconomic Inequalities in Kidney Disease and Transplantation**

The development of kidney disease and the process of kidney transplantation are multistage processes, and socioeconomic disparities may arise at each stage. First, a member of the population may develop chronic kidney disease (CKD). Second, chronic kidney disease may progress into ESRD. Third, those with ESRD may seek treatment with dialysis, kidney transplantation, or both. Fourth, those who seek a kidney transplant may or may not be referred to a nephrologist for transplant evaluation, may or may not be

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\(^{24}\) Previously, HLA-A and HLA-B matches were awarded points as well, but with the increasing potency of immunosuppressive regimes these prioritizations have been eliminated in the allocation algorithm except in the case of perfect HLA matching across HLA-A, -B, and -DR loci. HLA-DR matching is still prioritized because, unlike HLA-A and HLA-B, with modern immunosuppressant drugs matching at this locus is still associated with substantially improved post-transplant outcomes.
deemed a suitable candidate for transplantation, and if deemed suitable for transplant may or may not successfully enroll on the kidney transplant waiting list. Among those on the kidney transplant waiting list, some individuals will obtain a kidney transplant (from either a deceased or living donor), while others will die before this occurs. Finally, among patients obtaining a kidney transplant, some will experience graft failure (better known as organ rejection), in which case they may or may not re-enroll on the kidney transplantation waiting list, and still others will die from a rejection episode or from unrelated causes. Social inequalities can potentially arise at any of these stages; indeed, there is evidence that they do so at all of them.

**Chronic Kidney Disease and End-Stage Renal Disease Development**

Chronic kidney disease is typically measured as low estimated glomerular filtration rates or else by albuminuria. CKD is strongly related to increasingly prevalent health conditions such as diabetes mellitus, hypertension, and overweight. ESRD occurs when one’s kidneys permanently fail to function. Studies of the development of CKD and ESRD uniformly find that socioeconomic status, variously measured, is inversely related to these outcomes (Shoham et al. 2008; Ward 2008; Young et al. 1994).

**Transplant Evaluation and Waiting List Enrollment**

A number of studies find that ESRD patients from lower SES backgrounds are less likely to successfully enroll in the kidney transplant waiting list (Patzer et al. 2009; Schaeffner et al. 2008; Schold et al. 2011; Winkelmayer et al. 2001). Perhaps most revealing is a study (Furth et al. 2003) which used a vignette nephrologist survey design. Comparing children with identical medical conditions, nephrologists in the survey were
48% more likely to recommend transplantation for children of college educated parents than children whose parents did not finish high school.

Furthermore, socioeconomic differences in the timing of waitlisting are consistently observed. Shorter times on dialysis, preferably none at all, are associated with improved post-transplant outcomes, and patients with college or postgraduate educations are significantly more likely to enroll ‘preemptively’ without initiating dialysis first (Keith et al. 2008). Additionally, UNOS permits enrollment in whichever, and as many, local kidney transplant waiting lists one desires. Patients from higher SES backgrounds are significantly more likely to do both (Axelrod et al. 2010; Merion et al. 2004).

**Obtaining a Kidney Transplant**

Research on the association of socioeconomic status with one’s odds of obtaining a kidney transplant is relatively sparse compared to other fields of research, perhaps due to the lack of a full range of SES measures in the UNOS administrative dataset. However, evidence suggests that SES is associated with significantly improved odds of obtaining a kidney transplant (Axelrod et al. 2010; Gaylin et al. 1993; Ozminkowski et al. 1998). Ozminkowski and colleagues (Ozminkowski et al. 1998) found that the effect of SES on kidney transplant outcomes is sufficiently large that eliminating this effect would shift 30-65 transplants from higher to lower SES patients. Axelrod and colleagues (Axelrod et al. 2010) found that a significant component of the SES advantage in kidney transplantation occurs in living donor kidney transplants (LDKTs), for which patients in the highest SES quartile have a 76% higher likelihood compared to the lowest SES quartile.
Post-Transplant Outcomes

After one receives a kidney transplant one is subject to hazards of graft failure and death, the latter due either to kidney disease or unrelated causes. Higher socioeconomic status is associated with lower hazards of graft failure (Goldfarb-Rumyantzev et al. 2006; Stephens et al. 2010) and patient mortality (Axelrod et al. 2010; Goldfarb-Rumyantzev et al. 2006). This may be explained by the negative association of SES immunosuppressant adherence (Garg et al. 1999; Gordon et al. 2008). Additionally, higher SES is associated with shorter times on dialysis pre-transplantation (Kasiske et al. 1998; Keith et al. 2008) and higher odds of LDKT, both of which are associated with improved post-transplantation outcomes.

Limitations of this Literature

Research on socioeconomic disparities in kidney transplantation has been hampered by a failure to account for the dependencies of this process. First, in the context of a shortage of deceased donor kidneys for transplantation, individual prospects for transplantation are inherently interdependent, violating the assumptions of all regression-based analytical techniques used in most research on this topic (Lee and Wang 2003). Furthermore, at both the waiting list and post-transplant stages of the kidney transplant process, patients are subject to competing risks – while on the waiting list, of LDKT, DDKT, and death; post-transplantation, of graft failure and death – which also violate the assumption of standard survival modeling strategies.

Finally, standard regression analysis techniques generally treat survival times as a black-box process whose timing is associated with a range of time-variant and –invariant covariates. While this may be the best that can be expected in many cases, in the case of
kidney transplantation it is far more informative (and uniquely feasible) to model this process directly to understand the role of different factors in the allocation algorithm and kidney transplant system.

**Data and Methods**

**United Network for Organ Sharing STAR Files**

Since 1987, the United Network for Organ Sharing (UNOS) has collected detailed information on every organ transplant recipient, donor, and candidate in the U.S., containing information on the demographic, socioeconomic, medical status, laboratory, and medical treatment characteristics of each such person. Importantly, all ESRD patients are required to enroll in the kidney transplant waitlist, even if they have already identified a living donor. Therefore this database contains information on all legal transplant candidates and donors in the U.S. since 1987. Due to limitations in the availability of key data, the present analysis employs only transplant candidates enrolled in the KT waitlist on 7/1/2000 and all candidates and donors who entered the system subsequently. Additional KT candidate enrollments after 7/1/2000 were not included in the analytical dataset.

When each candidate is added to the kidney transplant waitlist, demographic (gender, area of residence, race/ethnicity, citizenship, education, age, etc.), medical, and laboratory information is collected on the patient. While the form permits multiple race categories to be entered, in the UNOS STAR file race information is coded exclusively in the following categories: white, black, Hispanic, Asian, Native American, Pacific Islander, and multiracial. These categories were recoded into non-Hispanic white, non-Hispanic black, Hispanic, Asian/Pacific Islander, and ‘other’ categories. Education is
measured in the following categories: none, some but no high school diploma, high school diploma or equivalent, college attendance but no college degree, baccalaureate or associate’s degree, and post-graduate education. ABO and HLA typing and PRA are calculated at the center at which the patient is evaluated. Information on the insurance coverage, U.S. citizenship status, educational attainment, date of waitlist enrollment, and a wealth of health status measures were collected for all candidates.

Candidate outcomes are recorded for each of the major outcomes which can occur, along with the dates at which this occurred: DDKT, LDKT, mortality, and graft failure (kidney rejection). Information on the HLA and ABO genotypes, race, gender, date and cause of death (if applicable) and relationship with the donor (if applicable) were recorded for all deceased and living donors who entered the system during this time, along with a wealth of medical status and history information.

Missing data in this dataset were addressed by imputation using hotdeck imputation methods based on patient age, ethnicity, gender, and education (e.g., Allison 2001; Reilly 1993). In hotdeck imputation, discrete groups are assigned to each observation (here, the demographic attributes just described), then non-missing values for the missing variables are drawn at random from other members of that group, proportionate to their representation in that subpopulation. Hotdeck imputation methods are widely used by government agencies such as the Census. Although multiple imputation and direct maximum likelihood methods are generally preferable, the very large size of the datasets involved and the low rates of missingness of key variables made
hotdecking, which is a computationally more efficient imputation method, an attractive option for this study.\footnote{Rates of missingness were generally low, and nearly nonexistent for demographic variables. The average rate of missingness for the HLA genes, however, was 6.4\%, but nearly all participants had at least one valid such measure per locus. Missing genetic data were not imputed; instead, following UNOS procedure in such cases, such persons were assumed to be homozygous at that locus. Two additional key variables had non-trivial rates of missingness in the dataset – OPO (29.1\%) and PRA (58.7\%). However, no cases were missing regional affiliation or key outcomes.}

Methods

As described above, analyzing the major determinants of socioeconomic inequalities in KT poses a number of analytical challenges which render most standard regression-based analysis approaches inadequate. Rather than a mere list of analytical difficulties, however, these characteristics of the KT system provide an opportunity. Crucially, the process by which deceased donors and transplant candidates are linked is publicly available and algorithmic in nature, meaning that it can be computationally reproduced. While this advantage does not apply to other key outcomes (LDKT, mortality, graft failure, and kidney offer acceptance), these outcomes can be simply analyzed in a manner which captures group-specific risks of different outcomes at each stage of the KT process. To account for these characteristics of the KT system, simulation-based methods will be used in this study. The goals of this analysis are twofold: first, to reproduce the basic functioning of the KT system; and second, to understand the degree to which different proximate determinants of KT outcomes are primarily responsible for socioeconomic inequalities in the KT system.

The Kidney Transplantation Simulation

The design of the simulation employed in this study is depicted in Figure 2. First, the initial waiting list is established. All transplant candidates who were on the waiting
list on July 1, 2000 are included on the baseline waiting list. Once the waiting list is established for this date, the dynamics thereof are simulated in 90-day increments through January 1, 2010, adding unique candidates as they joined the waiting list for the first time in this time window.

Once on the waiting list one may exit it in one of three ways – death, DDKT, or LDKT. Hazards of waiting list mortality are estimated separately for each race- and education-specific group for each 90-day time period through approximately the first three years of waiting list time using life table techniques. Hazards thereof for the fourth and fifth years on the waiting list are estimated by calculating the race- and education-specific hazards pooled over those years of waiting list time, as are hazards for time periods beyond the fifth year. Hazards of obtaining an LDKT are identically calculated. Those simulated to die are eliminated from the simulation, whereas those simulated to obtain an LDKT are moved to the post-transplant stage.

Third, one may exit the waiting list by obtaining a DDKT. These events are simulated by reproducing the functioning of the kidney allocation system as described above. The priority rankings of each KT candidate for each kidney are converted to allocation scores in which higher values represent higher priorities. Payback credit obligations and prior living donor statuses are not accounted for in this simulation, nor are subnational variations in the allocation system or the specific rules for ECD kidneys. An additional limitation of this analysis is that the allocation algorithm simulated here –

26 Although 90-day increments are somewhat arbitrary, given the computational intensity of this research design, a coarsening procedure was necessary in the interests of computationally feasibility.

27 Since hazards are modeled in 90-day increments, four such periods add up to only 360 days, not 365. ‘Year’ is used as a linguistically convenient term for 360 day periods for the duration of this paper. Years 3, 4, and ≥5 are analyzed jointly because a) similar hazards applied during these time spans and b) to ensure sufficient observations for stable estimates.
as such, the results of this simulation may be interpreted as the determinants of inequalities if the present national allocation system had been used since 2000.

The result of this procedure is a candidate-by-donor matrix of allocation priority scores. The rows of this matrix represent each of the transplant candidates simulated to be awaiting a transplant, and the columns represent each of the DDKs which were transplanted during this 90-day time period. DDKs are ‘offered’ sequentially to KT candidates in order of their priority scores among those who have been simulated to accept the offer if received.

Probabilities of offer acceptance are estimated using a logistic regression procedure, as a function of KT candidate and donor characteristics as well as their ABO and HLA histocompatibilities. The regression coefficients are multiplied by the relevant candidate and donor characteristics and candidate-donor histocompatibilities, and then converted to predicted probabilities of offer acceptance. These predicted probabilities are then compared to a random uniformly distributed variable to generate acceptance outcomes. Once this procedure has been completed, the probability of HLA positive crossmatch is estimated as

\[ P(XM) = PRA \left( \frac{6 - M_{ik}}{6} \right) \]

(1)

where XM is a positive crossmatch, PRA is the panel reactive antibody score for that patient, and \( M_{ik} \) is the number of HLA matches for that candidate-donor pair. The second term adjusts the PRA value using the proportion of non-equivalent HLA alleles for that candidate-donor combination. Transplant candidates simulated to be presensitized to the donor are not offered the DDK.
Among the candidates simulated to accept the transplant conditional on being offered and who are not simulated to be positively crossmatched with the donor, the kidney is awarded to the patient with the highest priority score for that kidney. Those candidates simulated to receive a DDKT through this procedure are moved to the post-transplant condition within the simulation.

Once one has received a transplant, one may exit the post-transplant condition through one of two ways – death and graft failure. Hazards of both outcomes are estimated as described above for waiting list mortality. Those who die exit the simulation, but those who experience graft failure may or may not return to the waiting list to seek another transplant. The probability of re-waitlisting was estimated using logistic regression techniques (results not shown), and post-transplant persons are, conditional on experiencing graft failure, returned to the waiting list proportionally the resultant predicted probabilities.

This simulation is repeated for each of the counterfactual conditions described above – equalizing place of residence, probabilities of DDKT offer acceptance, mortality hazards, living donor hazards, graft failure hazards, PRA, and ABO/HLA values. The effects of these counterfactual conditions are then calculated as

$$\beta_{OC} = 100 \frac{(\bar{X}_{RB} - \bar{X}_{OB}) - (\bar{X}_{RC} - \bar{X}_{OC})}{(\bar{X}_{RB} - \bar{X}_{OB})}$$

where $\bar{X}_{RB}$ represents the mean outcome for the reference education category (high school education) in the baseline simulation; $\bar{X}_{OB}$ represents the mean outcome for another educational group in the baseline simulation; $\bar{X}_{RC}$ represents the mean outcome for the reference education group in the counterfactual condition C; and $\beta_{OC}$ may be interpreted as the percentage of the gap between group O and the reference education
group for this outcome ‘explained’ by equalizing the factor C. In other words, \( \beta_{OC} \) is the estimated percentage of the gap between this group and the reference education group which would not be observed if there were no educational differences in the counterfactual variable C.

**Results**

**Educational Inequalities in Outcomes over Time**

Figure 3 shows educational patterns of transplantation outcomes over time by yearly cohorts on the kidney transplant waiting list. In each panel, the risk ratio of the indicated educational group for deceased donor and living donor kidney transplants is shown relative to those with post-graduate educational attainments for the waiting list cohort in question. A consistent pattern is observed – rates of LDKT are substantially higher for higher educated groups, and rates of DDKT are substantially higher for lower educated groups. While there are cohort fluctuations in this relationship, this pattern has been relatively stable over time.

Although one might characterize this as socioeconomic equality through divergent mechanisms, this pattern of transplantation outcomes is a substantial source of advantage for better educated transplant candidates. One typically has to wait for less time for an LDKT than for a DDKT, and LDKTs are associated with improved post-transplant outcomes compared to DDKTs. Although these divergent patterns result in similar rates of transplantation, not all transplants yield equal benefit, and higher educated persons are disproportionately obtaining the preferred type of transplant.

Figure 4 shows patterns, identically calculated, of mortality and post-transplant graft failure outcomes. Mortality outcomes on the waiting list and post-transplant are
combined for this figure. This figure reveals an additional source of socioeconomic advantage in the kidney transplantation system – higher educated persons generally have lower hazards of mortality and graft failure than do their lower educated peers. Although this relationship is subject to considerably greater yearly fluctuations than those for transplantation, the overall pattern suggests that the lower mortality and graft failure rates of higher educated persons are a source of substantial advantage among those in the ESRD population.

**Kidney Transplant Waiting List Demographic Composition**

Table 1 presents the distribution of hotdeck imputed demographic and PRA characteristics of the kidney transplantation waiting list by educational attainment. As can be seen, males, older persons, and African Americans are substantially overrepresented on the kidney transplant waiting list. Racial patterns of educational attainment are largely preserved, with whites and Asians composing a larger proportional share of the better educated groups than do black and Hispanic patients. Finally, a stark, inverted-U relationship is observed between educational attainment and PRA scores, such that those with high school or equivalent educational levels have the highest average PRA values while those in the no and the maximum education have the lowest average PRA values.

These patterns suggest two major demographic sources of advantage for better educated persons in the kidney transplant system. First, whites are more likely to be

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28 The sharp upticks in graft failure risk ratios in the final year of the graph likely reflect educational differences in rates of acute rejection, which generally happens much more quickly than chronic rejection episodes post-transplantation. This difference should be interpreted in light of the very short followup time observed for patients entering the kidney transplant waiting list in 2009.

29 A few of the age-education intersections in this table are unlikely, such as the small percentage of 0-17 year olds shown to have a college degree. These differences are the result of the hotdeck procedure.
better educated in this subpopulation as in the general population, and whites have a higher average probability of favorable HLA and ABO matching in the DDKT system (Daw 2011). Second, because of their lower average PRA scores better educated persons are less likely to positively crossmatch with potential DDKT or LDKT donors, which would generally preclude transplantation.

**Deceased Donor Kidney Offer Acceptance Model**

For various reasons most DDKT offers are not accepted by the designated recipient. Furthermore, the probability that such an offer will be accepted varies substantially by the characteristics of the transplant candidate, the histocompatibility between the donor and candidate, the candidate’s health, and the medical history of the deceased donor. Table 2 presents the result of a logistic regression model of offer acceptance behaviors, the results of an analysis of every DDK offer made to candidates between 7/1/2000 and 2/26/2010. The results of this analysis are presented in four different models. Model 1 presents the results of an analysis conditional on the characteristics of transplant candidates only; Model 2 adds controls for candidate-donor histocompatibility; Model 3 also controls for indicators of candidate health; and Model 4 adds controls for the deceased donor’s characteristics.

The results of this analysis show that lower educated persons are typically more likely to accept a DDK offer than are better educated candidates. Those with some schooling but no high school diploma are the most likely to accept an offer, followed by those with a high school diploma, some college, a bachelor’s or associate’s degree, no education, and those with a post-graduate degree. These differences are partially mediated by the distribution of ABO and HLA matches – group differences are reduced
overall in this model, though the post-baccalaureate differentials is slightly increased. Adding controls for candidate health substantially reduce these differences, as well, although these once again accentuate the difference between those with post-baccalaureate degrees compared to those with no education. Finally, the results of Model 4 reveal that group differences in DDK characteristics partially suppress these differences.

Although the lower average health status of lower educated patients partially mediate this difference, transplant candidates differ substantially in their odds of accepting a DDK offer, such that those with the highest educational attainment are the least likely to accept an offer, followed by those with no education, those with bachelor’s or associate’s degrees, some college, a high school diploma or equivalent, and those with some education but no high school diploma. These findings have at least two important implications for the present analysis. First, in terms of one’s odds of getting a DDKT while on the waitlist, this suggests that offer acceptance probabilities are a source of advantage for less educated patients on the kidney transplantation waiting list. Second, however, these results may indicate that worse educated persons are less selective in the DDKT offers they are willing to accept, perhaps because of their worse overall health condition on average compared to their higher educated counterparts.

**Baseline Simulation Results**

Table 3 compares the proportions of different transplantation outcomes in members of three different educational groupings (high school or equivalent, some college, and those with a college degree or higher), comparing the observed data to the simulated outcomes per waiting list or post-transplant spell. (Those with no education or
less than high school education are omitted because of the confounding of age with education, which masks the socioeconomic gradient in outcomes.) The proportion in each group observed and simulated to have each outcome is listed, as well as the risk ratio of that outcome compared to the BA+ category in both the simulation and the observed data. Finally, the percentage by which that group’s outcome is under or overestimated is listed for each outcome and grouping.

The model does have some limitations. First, overall rates of transplantation are underestimated, driven largely by substantially lower rates of DDKTs in the high school and above education categories. Second and relatedly, rates of waiting list mortality are overestimated for all groups, and post-transplant mortality rates are relatively imprecise for the bachelor’s degree and post-bachelor’s educational categories.

Although imperfect, the simulation model does capture educational differences in waiting list outcomes. As in the observed data, those with some college experience or a four-year degree are slightly comparably likely as those with a high school education only to obtain any kidney transplant, somewhat less likely to obtain a DDKT, and substantially more likely to obtain an LDKT. Similarly, rates of mortality for these groups are lower than for those with only high school educations, both while on the waiting list and post-transplant. Finally, group differences in post-transplant outcomes are relatively well captured, with the exception of the bachelor’s-high school comparison for post-transplant mortality.

However, some differences in outcomes are to be expected in the simulation compared to the observed data. First, the simulation uses only the national allocation scheme, ignoring subnational variations. To the degree that these subnational variations
in the allocation scheme shuttle kidneys to members of different racial groups within educational categories (which is the purpose of some of these programs), educational differences in the odds of post-transplant outcomes will be biased. Second, differences in the observed data versus the simulation in one area will influence others. For instance, the overestimation of waitlist mortality may be the direct result of the underestimation of DDKT rates in these educational strata, which may be the result of the failure of the simulation to account for subnational variations in the DDK allocation algorithm. Future research will attempt to ameliorate these discrepancies between the observed and simulated outcomes.

However, by and large the baseline simulation does capture group differences in major kidney transplantation outcomes, and differences in the counterfactual effects of different proximate determinants of these outcomes should still prove informative.

**Counterfactual Effects**

The counterfactual estimates calculate the percentage of the educational inequalities in kidney transplant outcomes explained by equalizing different proximate determinants of kidney transplantation outcomes (Table 4). Seven different counterfactuals are considered – genetics (ABO and HLA distributions), graft failure hazards, living donor hazards, mortality hazards, probabilities of offer acceptance, PRA, and place of residence.

The results show that educational differences in hazards of LDKT, place of residence, and PRA are the major causes of socioeconomic differences in transplantation rates. All else equal, equalizing LDKT hazards results in a substantial increase in educational disparities in outcomes, as lower educated persons are disadvantaged in this
outcome compared to other groups. Similarly, equalizing genetic distributions would increase approximately the gap between the lowest educated and higher educated groups by 18% (some college), 36% (four-year degree), and 26% (post-baccalaureate degree), showing that those in higher educated strata are advantaged by the inclusion of these factors in the kidney allocation system.

By comparison, higher educated groups are disadvantaged by their places of residence and lower average PRA scores. Equalizing the distribution of OPO memberships by education would result in a 47% (some college), 95% (four-year degree), and 107% (post-baccalaureate) reduction in simulated outcomes compared to the high school only education group. Even larger effects are observed for PRA scores, the equalization of which would result in a reversal of educational differences in transplant outcomes for those with a college degree or higher, and a substantial amelioration (80%) for those with some college experience. Although this finding is counterintuitive in light of the lower average PRA scores of higher educated persons, it should be kept in mind that in the simulation model the effect of PRA scores interact with the degree of HLA match degree between donor-candidate pairs, so the effects of this equalization are not straightforwardly interpretable.

**Discussion**

Chronic kidney disease and end-stage renal disease are large and increasing sources of ill-health in American society and an increasing site of socioeconomic inequalities in health. Although a great deal of attention has been paid to socioeconomic gradients in health in a wide variety of outcomes, kidney disease has received relatively little attention (Shoham et al. 2008). A major downstream process associated with the
increasing prevalence of CKD and ESRD is the increasing pressures in the kidney transplantation system. The present study investigates the nature and proximate determinants of socioeconomic inequalities in this system.

In terms of whether one obtains a kidney transplant, socioeconomic inequalities in this system are small – a transplant candidate with a college degree or higher is only about 5% more likely to obtain a transplant than someone with only a high school diploma. Yet transplant candidates with different levels of education have highly divergent experiences in the kidney transplantation system, and these differences have large implications for the degree of suffering and risk of further ill health and mortality to which participants in this system are subject. Those with higher educational attainments have slightly higher rates of transplantation compared to their less educated counterparts, are more likely to obtain an LDKT, substantially less likely to obtain a DDKT, and less likely to die or experience graft failure while in the kidney transplantation system. Educational differences in transplantation outcomes are marked by divergent sources of advantage and disadvantage for each educational group. The higher rates of LDKT for higher educated persons are a major source of advantage for these groups, as is their greater average genetic similarity to the DDKT donor pool. However, lower educated persons generally live in areas with shorter waiting times, and equalizing PRA scores result in advantages for lower educated persons in this kidney transplantation system.

These findings suggest future directions for the literature on socioeconomic inequalities in health generally. First, the absence of large disparities in the end result of a health process does not mean that SES is irrelevant for that health outcome. In the case of kidney transplantation, the differences in the odds of obtaining a kidney transplant are
comparatively minor, but higher educated and lower educated patients reach this result with very different processes. Second, these findings highlight the fact that health is not an indivisible thing with respect to socioeconomic status. Even restricting our view to kidney disease alone, SES disparities in the development of CKD are far larger than those associated with kidney transplant outcomes once one joins the waiting list.

Third, this research highlights the likelihood that there is no uniform set of mechanisms linking socioeconomic status to health. Although I agree with others (e.g., Adler and Rehkopf 2008) that identifying these mechanisms are an important challenge facing this literature, it is unlikely that the mechanisms of inequality identified in this research – particularly, geography and histocompatibility genes – mediate other SES-health relationships. Instead of looking for a single set of mediators, we should investigate the diversity of mechanisms linking SES and other measures of social position with health outcomes.

Of course, the ability of this study to capture the major mechanisms of socioeconomic inequality in kidney transplant outcomes is unlikely to be universally available to studies of other health inequality processes. A major advantage of this study was the availability of high quality data on all participants in a relatively closed system in which the proximate determinants of outcomes were relatively well-defined. Although researchers should continue to seek out such opportunities, the quality of data and information on the kidney transplantation system is unlikely to be found in most areas of health research.

Like all studies, the findings of this investigation raise additional questions. This analysis did not account for the role of multiple waitlisting, family financial hardships
post-transplantation, preemptive waitlisting, family and social network dynamics and characteristics, local waiting list dynamics and transplant center position in the kidney exchange network, the process of DDKT offer acceptance, and other likely mechanisms of social inequalities in sub-processes within the kidney transplant system. Future research should continue to investigate the contributions of these factors to the disparities in waiting list and post-transplant outcomes documented here.

A key goal of this analysis was to maintain maximum simplicity in the simulation of the kidney transplant system. However, viewed in another light the simplicity of the model is also a limitation. For instance, demographic variation in mortality, graft failure, and LDKT besides those associated with the intersections of race and education are not accounted for in this analysis. Similarly, the role of OPO paybacks and debts and rates of previous living donation – both key factors in the kidney allocation algorithm – are not accounted for in this analysis. Future research should seek to incorporate these additional processes into studies of the kidney transplantation system.

Finally, although the simulation models presented in this paper capture socioeconomic inequalities in the kidney transplant system reasonably well, they are not perfect. Future research should seek to fine tune this model to better represent the system and its dynamics. In conclusion, this study documents the degree and proximate determinants of educational inequalities in the kidney transplant system between 2000 and 2010. The results indicate that while group differences in receipt of any kidney transplant are small, differences in the means by which members of different groups obtain this result are large. Higher educated persons in this system are advantaged by their greater odds of obtaining a living donor kidney transplant and their higher
probability of genetic matching with the deceased kidney donor pool. In contrast, lower educated persons are advantaged primarily by their residential geography and the effect of immunological sensitivities. Future research on kidney transplantation can further the contributions of this study by accounting fully for the systemic nature of kidney transplantation.
References


Tables and Figures

Figure 3.1: Deceased Donor Kidney Allocation National Algorithm, 2003-Present

NOTE: This figure represents the national kidney allocation priority algorithm since 2003. This does not represent local variations in allocation policy. Read left to right, each subsequent level reflects priorities within categories of the columns to the left, and categories closer to the top (for the first three levels) are higher priorities.
Figure 3.2: Simulation Design

- Population → Enter Waitlist
- Waitlist → Deceased Donor Transplant
- Post-Transplant → Deceased
- Deceased → Post-Transplant Mortality

*: Simulated using Life Tables
†: Timing determined using Observed Event Date
#: Simulated using UNOS Kidney Allocation Algorithm and Offer Acceptance Model
Figure 3.3: Trends in Educational Inequality in Transplantation Outcomes, 1990-2009

NOTE: Figures plotted are the risk ratio of the indicated educational group to that of those with post-graduate degrees for the outcome in question. Years indicate the year individuals joined the kidney transplant waitlist. Those joining the waitlist in 1990 or earlier are collapsed into the first (1999) category. Those joining in 2010 are omitted.
Figure 3.4: Trends in Educational Inequality in Mortality and Graft Failure Outcomes, 2000-2009

NOTE: Figures plotted are the risk ratio of the indicated educational group to that of those with post-graduate degrees for the outcome in question. Years indicate the year individuals joined the kidney transplant waitlist. Those joining the waitlist in 1990 or earlier are collapsed into the first (1999) category. Those joining in 2010 are omitted.
Table 3.1: Descriptive Statistics, Kidney Transplant Waitlist, 2000-2010

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NOTE: Values for demographic categories are percentages; values for PRA are means and standard deviations, as indicated. Data on kidney transplant waitlist composition from 7/1/2000 through 2/26/2010. SOURCE: UNOS STAR files.
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<td>EDUCATION</td>
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<td>56</td>
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<td>Candidate health controls?</td>
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<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Donor characteristic controls?</td>
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<td>No</td>
<td>Yes</td>
</tr>
<tr>
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<td>0.04</td>
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<tr>
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<td>1,189,243</td>
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<td>745,990</td>
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<td>-148,616</td>
<td>-111,577</td>
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<td>0.1196</td>
<td>0.1933</td>
<td>0.1942</td>
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</table>

NOTE: Observations in this analysis are each deceased donor kidney offer event. Coefficients are presented as odds ratios. Standard errors and statistical significance tests are omitted because these results are based on a census of deceased donor kidney transplant
offers 7/1/2000 through 2/26/2010. Smaller sample sizes in columns (3) and (4) reflect observation omissions due to listwise deletion for missing data.
### Table 3.3: Observed and Simulated Outcomes by Education

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Education</th>
<th>Observed Data</th>
<th>Simulation</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td>Proportion</td>
<td>Ratio vs. BA+</td>
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<td><strong>Waiting List Outcomes</strong></td>
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<tr>
<td>Any Transplant</td>
<td>HS/GED</td>
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<td></td>
<td>Some College</td>
<td>0.377</td>
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<td></td>
<td>BA</td>
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<tr>
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<td>HS/GED</td>
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</tr>
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<td></td>
<td>Some College</td>
<td>0.258</td>
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<td>BA</td>
<td>0.252</td>
<td>0.902</td>
</tr>
<tr>
<td></td>
<td>&gt;BA</td>
<td>0.227</td>
<td>0.813</td>
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<td>LDKT</td>
<td>HS/GED</td>
<td>0.097</td>
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</tr>
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<td>Some College</td>
<td>0.119</td>
<td>1.224</td>
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<tr>
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<td>HS/GED</td>
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</tr>
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<td>Some College</td>
<td>0.167</td>
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<tr>
<td><strong>Post-Transplant Outcomes</strong></td>
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<tr>
<td>Graft</td>
<td>HS/GED</td>
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</tr>
<tr>
<td>Failure</td>
<td>College</td>
<td>0.190</td>
<td>0.893</td>
</tr>
<tr>
<td>--------------</td>
<td>------------</td>
<td>-------</td>
<td>-------</td>
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<table>
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<tr>
<th>Post-Transplant Mortality</th>
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<th>--</th>
<th>0.108 (0.103,0.111)</th>
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<th>-7.0</th>
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<tr>
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<td>0.104</td>
<td>0.896</td>
<td></td>
<td>0.098 (0.093,0.106)</td>
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<tr>
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<td>0.809</td>
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<td>0.110 (0.101,0.119)</td>
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<td>17.3</td>
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<td>0.897</td>
<td></td>
<td>0.091 (0.081,0.106)</td>
<td>0.953</td>
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NOTE: DDKT stands for deceased donor kidney transplant; LDKT stands for living donor kidney transplant. Percentage difference is the percentage by which the simulated proportions are different from the observed proportions.
### Table 3.4: Counterfactual Effects

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<tr>
<th>Education</th>
<th>Counterfactual</th>
<th>Any Kidney Transplant Proportion (90% Interval)</th>
<th>% Effect</th>
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<tr>
<td>HS/GED</td>
<td>None</td>
<td>0.300 (0.275,0.312)</td>
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</tr>
<tr>
<td></td>
<td>Genetics</td>
<td>0.299 (0.271,0.312)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Graft Failure</td>
<td>0.301 (0.277,0.313)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Living Donor</td>
<td>0.314 (0.290,0.325)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Mortality</td>
<td>0.301 (0.262,0.313)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Offer Acceptance</td>
<td>0.300 (0.275,0.312)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Residence</td>
<td>0.277 (0.249,0.289)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>PRA</td>
<td>0.257 (0.252,0.260)</td>
<td>--</td>
</tr>
<tr>
<td>Some College</td>
<td>None</td>
<td>0.278 (0.259,0.289)</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Genetics</td>
<td>0.273 (0.250,0.283)</td>
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</tr>
<tr>
<td></td>
<td>Graft Failure</td>
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<td>-2.95</td>
</tr>
<tr>
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<td>0.11</td>
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<tr>
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<td>Residence</td>
<td>0.266 (0.248,0.277)</td>
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<td>PRA</td>
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<tr>
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<td>Genetics</td>
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<td>Living Donor</td>
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<td>-251.09</td>
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<td>Mortality</td>
<td>0.289 (0.278,0.298)</td>
<td>1.50</td>
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<tr>
<td></td>
<td>Offer Acceptance</td>
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<td>0.31</td>
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<td>Residence</td>
<td>0.277 (0.264,0.288)</td>
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</tr>
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<tr>
<td></td>
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<td>-26.43</td>
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<tr>
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<td>Graft Failure</td>
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</tr>
<tr>
<td></td>
<td>Living Donor</td>
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<td>-237.62</td>
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<tr>
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<td>Mortality</td>
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<tr>
<td></td>
<td>Offer Acceptance</td>
<td>0.282 (0.267,0.295)</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Residence</td>
<td>0.279 (0.263,0.295)</td>
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<tr>
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<td>PRA</td>
<td>0.265 (0.257,0.276)</td>
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NOTE: ‘% Effect’ columns are the percentage of the gap in outcomes between the educational group in question and the HS/GED group eliminated in the counterfactual baseline compared to the baseline simulation.
Chapter Four: Racial Inequality in the Living Donor Kidney Transplant Opportunity Structure

Introduction

End-stage renal disease places a large and increasing burden on the health of the U.S. populace and disproportionately affects African Americans, primarily the result of African Americans’ higher prevalence of diabetes, hypertension, and overweight (Norris and Agodoa 2005). Primary treatments for ESRD include dialysis and kidney transplantation, of which the latter is the medically preferred treatment (e.g., Danovitch and Cecka 2003). Among those receiving transplants, living donor kidney transplantation (LDKT) is associated with substantially better medical outcomes than deceased donor kidney transplants (DDKTs; Davis and Delmonico 2005; Kasiske and Bia 1995; Mange et al. 2001). The kidney transplantation system has long produced substantial racial inequalities in rates and timing of kidney transplants, particularly for LDKTs – in recent years, African Americans have been less than half as likely as whites to experience this outcome (Meier-Kriesche et al. 2000). Although the majority of LDKTs come from recipients’ kin, to date no research on the determinants of racial inequality in LDKT has examined the role of kinship structure and attributes in the production of racial differences in LDKT.

Obtaining an LDKT is a four-step process. First, one must have access to a medically suitable living donor. One’s LDKT opportunity structure – the distribution of suitable potential kidney donors – is based on one’s kinship and friendship networks.
Second, a given alter must be agree to be evaluated for donation once they and the
candidate have discussed the possibility of donation. Third, the potential donor must be
deemed psychologically, medically, and genetically suitable to donate a kidney to the
patient. Finally, conditional on a favorable evaluation, the donation must actually occur.

Kinship structure and characteristics influence patients’ LDKT opportunity
structure in a number of ways. First and most obviously, larger families include more
potential kidney donors. Second, donors are evaluated in part by their degree of genetic
match with the transplant candidate, so the proportion of close genetic relatives will
influence one’s transplant prospects. Third, donors must be sufficiently healthy to donate.
Race is well known to be related to family structure (Angel and Tienda 1982; Cohen and
Casper 2002; Hofferth 1984) and a wide range of health statuses (Blackwell et al. 2002;
Elo and Preston 1997; Kelley-Moore and Ferraro 2004; Manton and Gu 2001; Williams
2005), so these represent candidate mechanisms to explain black-white differences in
living donor transplantation.

Some additional genetic and immunological mechanisms embedded within
kinship structures may help to explain racial inequalities in LDKT as well. In the U.S.,
black populations have greater overall genetic diversity than whites (Liu et al. 2006;
Prugnolle et al. 2005a; Prugnolle et al. 2005b), which could lower the probability of a
sufficient genetic match between a patient and kin conditional on their expected genetic
relationship. Finally, racial differences in immunological reactivity (Cooper et al. 1995),
which influences the chances of immediate rejection, could partially explain black-white
differences LDKT.
This paper investigates black-white differences in the opportunity structure for LDKT, estimating group differences in kinship size, genetic relationship structure, kin health statuses, immunological sensitivity, and the probability of a genetic match by race. Based on data on the characteristics of kidney transplant candidates, other population data, and a simulation exercise, the present results suggest that blacks and whites actually have approximately the same probability (60%) of having one or more suitable living donors in their kinship networks. While each white kin is more likely to be a suitable donor, the larger average size of black kinship networks counterbalances this difference. These results suggest that far fewer ESRD patients are obtaining LDKTs than could do so, and that factors influencing the commencement and nature of the living donor search process are likely responsible for black-white differences in rates of LDKT. Finally, given the relatively sparse number of potential donors typically evaluated for donation (Weng et al. 2010), the higher probability that a given white alter will be deemed a suitable donor may help explain white-black living donor differentials.

**Background**

**Racial Inequality in the Transplantation System**

Kidney disease is an increasing source of morbidity and mortality in the U.S., driven in large part by population increases in the prevalence of hypertension, diabetes, and overweight (Daumit and Powe 2001; Malek et al. 2011; Norris and Agodoa 2005). Kidney transplants necessarily involve a donor and a recipient, and there are two major types of donors – the deceased and the living. Although the number of both types of transplants has grown since the beginning of widespread transplantation in the mid-1980s, the number of transplants has not kept pace with the number of transplant
candidates. Under these Malthusian conditions, the kidney transplant waiting list has
grown with the prevalence of ESRD, resulting in quickly lengthening waitlists for
kidneys for transplantation. By the end of 2008, the number of patients awaiting kidney
transplants had grown to 85,440, more than a 500% increase since 1988 and far
outstripping U.S. population growth.

Living donor kidney transplants (LDKTs) are associated with substantially better
post-transplant outcomes than are deceased donor kidney transplants (DDKTs; Davis and
Delmonico 2005; Kasiske and Bia 1995; Mange et al. 2001; Reese et al. 2009). Whereas
decceased donor kidneys are allocated to ESRD patients on a transplant waitlist according
to a priority algorithm, LDKTs are obtained more informally, typically from a donor in
the candidate’s kinship or friendship networks who is sufficiently healthy and genetically
compatible with the intended recipient to donate a kidney. In addition to the advantages
of LDKTs (compared to DDKTs) for patient survival and organ rejection, they also
typically involve a much shorter waiting period.

The burden of the increasing difficulty of obtaining a kidney transplant has fallen
disproportionately on African Americans, who are more likely than whites to need a
kidney transplant, and much less likely to obtain one. African Americans are less likely to
be evaluated for transplantation if they develop ESRD, are less likely to be placed on the
waitlist if they are evaluated, and typically have far longer waits for a deceased donor
transplant than do white transplant candidates (Epstein et al. 2000; Hall et al. 2011).
Longer periods of dialysis are associated with worse post-transplantation outcomes and
higher pre-transplant mortality rates (Eckhoff et al. 2007; Gordon et al. 2010),
contributing to African American disadvantages in the kidney transplantation system.
(Malek et al. 2011). Finally, African Americans are far less likely than whites to obtain a living donor kidney transplant. Compared to white patients, black patients are less likely to have a potential donor evaluated for donation, and are less likely to obtain a living donor transplant if they do have a potential donor (Weng et al. 2010). In fact, a recent analysis (Daw 2011) suggests that in the last decade racial differences in rates of LDKT are primarily responsible for overall racial inequality in transplantation rates.

**Studies of Living Kidney Donation**

Research on racial disparities in LDKT has focused on the determinants and outcomes of potential kidney donors who were brought into particular transplant centers for evaluation. First, much work investigates who has a potential donor evaluated for donation (Barnieh et al. 2011; Gordon 2001; Rodrigue et al. 2008; Zimmerman et al. 2006). These studies find that many candidates do not believe that they have anyone to discuss donation with (Barnieh et al. 2011). Additionally, while many candidates do have relatives and friends offer to be evaluated for donation, the majority of these offers are refused (Gordon 2001). A major concern among those who refuse such offers is concern for the risks posed to the potential donor. However, another study (Reese et al. 2009) find that younger candidates and those with higher yearly incomes were more likely to have a potential donor evaluated, and that whites were more than twice as likely as blacks to have had a potential donor evaluated. Furthermore, most candidates who do have a donor evaluated have two or fewer potential donors evaluated (Weng et al. 2010), suggesting that the vast majority of transplant candidates do not explore the full range of their kinship networks when seeking an LDKT.
Once a candidate-potential donor pair agrees to be evaluated for transplantation, here are two major obstacles to be overcome in this process: medical and immunological barriers, and procedural barriers. Concerning the latter, a recent study (Clark et al. 2008) found that the potential donors of patients with higher levels of instrumental social support were more likely to complete the full living donor evaluation process, which is a major site of racial inequality in LDKT. For those who are evaluated, many are excluded for poor health or poor immunological compatibility with the potential recipient, and African American potential donors are more likely to have this result (Lunsford et al. 2007; Reeves-Daniel et al. 2009).

These findings suggest a number of potentially important mechanisms of racial inequality in LDKT rates. First, they strongly indicate that transplant candidates do not have their full networks evaluated for transplantation. Only about half of transplant candidates have any donors evaluated, and the majority of those who do so have only one evaluation. Second, this suggests that racial differences in kin health could play a major role in white and black transplant candidates’ transplantation prospects, as could donor evaluation completion rates, racial differences in the probability of immunological compatibility, and the probability of having any potential donors evaluated.

However, these studies share some major limitations. Most importantly, none contain indications of the full distribution of kinship ties and disqualifying conditions for donation among the social networks of white and black transplant candidates. Although it is unlikely that racial differences in this ‘opportunity structure’ explain the entirety of racial differences in LDKT, this should be the starting point for any analysis of racial inequality in the LDKT system.
Determinants of the Living Donor Kidney Transplant Opportunity Structure

Because the vast majority of LDKTs involve kin donors, racial differences in the properties of their kinship networks are a prime candidate to explain racial differences in LDKT. Figure 1 illustrates the factors hypothesized to influence the probability of LDKT. This figure separates the mechanisms influencing the living kidney donation process into two major categories: factors influencing the LDKT opportunity structure, and factors influencing the probability of LDKT given one’s opportunity structure. Although this research investigates the first set of determinants only, in the following section the relevance of each of these factors for one’s LDKT opportunity structure will be discussed alongside previous findings on racial differences in these factors.

Factors Influencing the LDKT Opportunity Structure

*Kinship network size.* First, the number of living alters in one’s kinship network will be positively related to one’s prospects for an LDKT. All else equal, larger families will be associated with a more favorable LDKT opportunity structure, and racial differences in the distribution of kinship size are a potential explanatory mechanism for racial differences in LDKT. However, the literature on racial differences in kinship network structure is surprisingly sparse. The vast majority of the literature on race and kinship explores differences in household co-residence (e.g., Angel and Tienda 1982; Hofferth 1984), contact (e.g., Raley 1995), and support (e.g., Mazelis and Mykyta 2011; Sarkisian and Gerstel 2004) instead of the entire kinship structure itself. Although all of these variables may be related to kinship size and are important in their own right, in absence of a detailed literature on these factors this connection cannot be assumed. Nonetheless, given that African Americans have larger households on average (Choi
It is likely that African Americans have larger kinship networks on average than whites, which could prove a source of advantage in the LDKT opportunity structure.

**Genetic structure of kinship.** Second, because two forms of genetic similarity (red blood type and human leukocyte antigen compatibility, discussed below in detail) are associated with better transplantation outcomes and are used by medical staff to determine donor suitability, the structure of genetic relationships in one’s kinship networks is also an important determinant of one’s opportunity for LDKT. One has a higher probability of sharing genes in common with close genetic relatives (e.g., full siblings) than more biologically distant ones (e.g., cousins). Although the sparseness of the literature on racial differences in kinship structures limits what is known, the likelihood of larger average kinship networks among African Americans would also suggest that they have more close genetic relatives on average than whites.

**Kin Health Status.** Third, before an LDKT can occur, potential living donors are evaluated on a range of medical and psychological factors to determine their suitability for donation. The goal of these evaluations is to ensure that the potential donor is capable of making the donation decision, is doing so without coercion, and can donate a kidney with minimal risk to the donor and maximum potential benefit to the recipient. Racial patterns of psychiatric conditions and morbidity are more complicated than is often recognized. Although African Americans are subject to greater mortality rates (Rogers 1992) and higher morbidity overall (Fiscella et al. 2000; Williams and Collins 1995), there is considerable variability in racial disparities associated with specific medical conditions. For instance, although African Americans have higher prevalences of
hypertension (Hajjar and Kotchen 2003), diabetes (Cowie et al. 2006), and obesity (Ford et al. 2011), whites have higher prevalences of many psychiatric disorders (Kessler et al. 1994), chronic obstructive pulmonary disease (Bang et al. 2009), asthma (McHugh et al. 2009), and breast cancer (Ward et al. 2004). Furthermore, these diseases are not independent and are rarely studied jointly. However, due to the overall greater burden of morbidity on African Americans, a black disadvantage in rates of kin contraindications for donation is predicted.

Genetic compatibility. Fourth, African Americans are known to have greater genetic diversity than do whites in the United States, a result of historical migration patterns (Liu et al. 2006; Prugnolle et al. 2005a; Prugnolle et al. 2005b) and maintained by ongoing racial homogamy in the U.S., which could result in a disadvantage for blacks in their LDKT prospects. For kidney transplantation, two types of genetic compatibility are especially relevant – red blood cell type (measured by one’s ABO genotype), and white blood cell type (measured by one’s HLA-A, HLA-B, and HLA-DR genotypes). These genes play key roles in the human immune system and accordingly structure the probability of organ rejection, in which a transplanted kidney is attacked by the body’s immune system.

These genotypes structure the production of red blood cell (ABO) and white blood cell (HLA) antigens, which the immune system employs to differentiate host from foreign cells. Cells whose antigens do not contradict the host’s are ‘histocompatible’ and trigger no immune response; cells whose antigens differ from the host’s do trigger a response. Furthermore, certain pairs of ABO and HLA genotypes are ‘serologically equivalent,’ meaning that the immune system cannot differentiate them. A familiar
example is O type blood, which is the ‘universal donor’ blood type because it produces no antigens and therefore triggers no immune response when given to others in blood transfusions.

Racial differences in the distribution of ABO and HLA genes are thought to explain some portion of racial inequality in the cadaveric transplantation system (Higgins and Fishman 2006; Malek et al. 2011; Navaneethan and Singh 2006; Vamos et al. 2009). Although progress is being made in overcoming it, the ‘ABO barrier’ is a major obstacle to successful transplantation, sometimes triggering an immediate and devastating immune response when crossed (Nelson et al. 1992). While the effects of HLA mismatch are less severe with modern immunosuppression technology (Murphey and Forsthuber 2008; Su et al. 2004), higher HLA matches are nonetheless associated with improved post-transplantation survival prospects. Accordingly, racial differences in the probability of genetic similarity conditional on overall genetic relationship could partially explain racial differences in LDKT.

**Immunological presensitization.** Fifth, ESRD patients vary widely in the probability that another person’s cells will trigger a severe immune response, known as hyperacute kidney rejection. In the transplantation literature this probability is defined by Panel Reactive Antibody, or PRA, scores, which are a proxy for the probability of a positive crossmatch. Positive crossmatching occurs when a transplant recipient has antibodies to foreign antigens in the donated organ. As a primary mechanism of disease immunity, antibodies are produced by the body as a defense against cells displaying specific antigens. When cells displaying these antigens are encountered again, antibodies attack them much more rapidly and effectively than the body’s baseline immune
responses. As such, until recently transplanting a kidney into an ESRD patient who has already produced antibodies to the donor’s antigens resulted in nearly guaranteed and immediate kidney rejection. Lately therapies designed to avert this outcome have shown some promise (Haririan et al. 2009) but still lag far behind non-crossmatched transplants in patient and graft survival prospects.

African Americans on average have higher PRA scores than whites – in one early study, African Americans ESRD patients had an average score of 15% whereas white patients averaged 6%. Several factors may help to explain this. As with all antibodies, antigen presensitization is associated with prior exposure to foreign antigens. The primary mechanisms through which this occurs are prior transplantations, blood transfusions, and pregnancy (Leffell et al. 1997). Blood transfusion history may represent a major source of immunological presensitization disadvantage for African Americans (Kerman et al. 1992). Similarly, prior transplantation creates a higher likelihood of presensitization (Cooper et al. 1995). Finally, higher fertility, especially with different partners (Census 2011; Harknett and Knab 2007), could create racial differences in PRA as well.

In sum, I expect that African American transplant candidates will on average have larger kinship networks with higher counts of close genetic relatives, providing a source of advantage in the LDKT opportunity structure. However, I also expect that white transplant candidates will have healthier kin on average, a higher probability of HLA and ABO histocompatibility with their kin, and a lower probability of positive crossmatches. How these factors combine to structure racial differences in the LDKT opportunity structure is the subject of this research.
Factors Influencing the Probability of LDKT Given the LDKT Opportunity Structure

A number of processes likely mediate the translation of opportunity structures into LDKT outcomes. While these processes are not directly explored in the present analysis, they will prove helpful in understanding racial differences in LDKT conditional on opportunity structure.

The health care system. First, in order for the opportunity for LDKT to be translated into an LDKT outcome, assistance in navigating the bureaucracies and processes available in the kidney transplantation system will usually be required. For instance, a recent retrospective study found that black patients were less likely to recruit potential donors and, conditional on recruitment, less likely to complete a LDKT (Weng et al. 2010). It could be that differential promotion of and guidance in the LDKT process on the part of the health care providers could explain this difference.

Knowledge of and interest in transplantation. Much medical research on racial differences in transplantation focus on the role of racial differences in knowledge of, and interest in, transplantation (Navaneethan and Singh 2006). Thus patient preferences and beliefs are a central focus of the medical literature on disparities in kidney transplantation and a frequently cited site of potential intervention (Rodrigue et al. 2006; Waterman et al. 2006). However, the evidence on racial differences in these factors is mixed (Alexander and Sehgal 2001; Ayanian et al. 1999; Malek et al. 2011). Although perhaps overemphasized in the medical literature on kidney transplantation disparities, beliefs, preferences, and knowledge of transplantation is a theoretically plausible mediator of the relationship between LDKT opportunity and actual LDKT.
Kin relations. Finally, a major and understudied potential mediator of the relationship between LDKT opportunity structures and actual LDKTs is the nature of family relationships. Sociologically, LDKTs are a gift, and an unusually meaningful one. As with all gifts, LDKTs are passed across and potentially shape relations between giver and receiver and are usually subject to norms of reciprocity. Research on social support in black and white families suggests that they differ in the character and degree of support. For instance, while it is commonly claimed that racial and ethnic minorities have more closely knit kinship networks (Aschenbrenner 1975; Martin and Martin 1985; Stack 1974), other work finds that whites exchange assistance with greater frequency (Cooney and Uhlenberg 1992; Eggebeen 1992; Goldscheider and Goldscheider 1991; Hofferth 1984; Hogan et al. 1993; Hoyert 1990; Lee and Aytac 1998; Roschelle 1997), although the pattern differs for financial and instrumental support (Lee and Aytac 1998; Roschelle 1997; Sarkisian and Gerstel 2004). There is also evidence that black families tend to emphasize same-generation ties more than whites, while white families place greater emphasis on cross-generational ties (Johnson 2000; Johnson and Barer 1990; Johnson and Barer 1995). These relationship patterns by race may structure the probability of seeking or accepting LDKTs from one’s kinship network.

In general, gifts are subject to strong norms of reciprocity, yet rarely can a gift of the magnitude of another’s organ be adequately be repaid, which potentially crates a creditor/debtor relationship between the kidney donor and recipient. Fox and Swazey’s (1978, 1992; see also Healy 2006) seminal work on the subject termed this the “tyranny of the gift” due to the strains such an extraordinary gift places on the relationship between donor and recipient. Transplant candidates’ willingness to accept such a gift may
fundamentally depend on their relationships with their kin and their belief in their ability to weather such potential tyrannies. As with all requests and offers for assistance, there are patterned expectations for resource exchanges (Bengtson et al. 1996; Lindblad-Goldberg 1987; Miller-Cribbs and Farber 2008; Neighbors 1997; Nelson 2000; Stack 1974; Tracy 1990), and one’s ability to fulfill reciprocal exchange relations may influence one’s willingness to accept assistance. Furthermore, there is substantial evidence that these familial exchange norms are of particular importance to African Americans due to traditional norms of mutual family support in impoverished circumstances (Malson 1983; Martin and Martin 1985; McAdoo 1982; Miller-Cribbs and Farber 2008; Testa and Slack 2002). If these patterns are reproduced for social relations of kidney exchange, this suggests a potential mechanism of LDKT inequality. It could be that the lower ability of African Americans to reciprocate such important gifts, combined with stronger norms of reciprocal exchange, could lead African Americans to decline these gifts at higher rates than whites.

**Analytical Strategy, Data, and Measures**

Studying racial differences in the LDKT opportunity structure presents a number of analytical difficulties, the foremost of which is that the requisite information is not available in a single dataset. However, with some assumptions many of these factors may be explored using existing data. The goal of this study is to measure demographically typical kinship networks and health status patterns, accurately assign probabilities of genetic and immunological compatibility, and then calculate the number of suitable available living donors in candidates’ simulated kinship network. To illustrate, figure 2 presents a hypothetical kinship structure (represented as a modified ore graph) where the
black dot represents the ESRD patient, each pie graph represents a member of their
kinship network, and the blue slice in each pie graph represents the probability that that
member of the network is a suitable living kidney donor for the ESRD patient. Once this
kinship structure and its attributes is constructed, simulating the patient’s LDKT
opportunity structure is relatively simple, as discussed below. To reach this goal the
analysis proceeds in a number of steps, drawing separately on information on
demographic patterns of transplantation-relevant genes, biologically-informed kinship
structure, and health statuses which would disqualify one as a living kidney donor.

**The Living Donor Kidney Transplant Opportunity Structure Simulation**

To generate a data-driven simulation of white-black differences in the LDKT
opportunity structure, 100 simulations (ten each for each imputation of the UNOS
dataset, described below) were conducted to measure simulated opportunity structures
while allowing for random noise from the simulation process.

**Information on Transplant Candidates**

First, demographic, genetic, and immunological information on transplant
candidates were employed to obtain estimates of the race-specific distribution of ABO
and HLA genotypes and to calculate the probability of positive crossmatches between
donors. Demographic characteristics (race, age, education, and gender) are conserved for
use in probabilistically matching transplant candidates to other needed attributes, as
discussed below.

*D dataset: United Network for Organ Sharing STAR Files. Since 1987, the United
Network for Organ Sharing (UNOS) has collected detailed information on every organ
transplant recipient, donor, and candidate in the U.S., containing information on the
demographic, socioeconomic, medical status, laboratory, and medical treatment characteristics of each such person. Importantly, all ESRD patients are required to enroll in the kidney transplant waitlist, even if they have already identified a living donor. Therefore this database contains information on all legal transplant candidates in the U.S. since 1987.

Although this dataset contains information on the social (and sometimes biological) relationship LDKT recipients had with their donors, information on the full social networks of transplant candidates is lacking. Nonetheless, it is useful in analyzing the distribution of demographic, genetic, and immunological characteristics of persons on the kidney transplant waitlist in the U.S. Whites and blacks only were used in the present analysis due to sampling frame limitations of the kinship data used, as discussed below. ABO and HLA typing and antibody screening is performed at the center at which the patient is evaluated.

Ten different imputations were produced from this file using hotdeck imputation methods based on patient age, ethnicity, gender, and education. In hotdeck imputation, discrete groups are assigned to each observation (here, the demographic attributes just described), then non-missing values for the missing variables are drawn at random from other members of that group, proportionate to their representation in that subpopulation. Hotdeck imputation methods are widely used by government agencies such as the Census. Although multiple imputation and direct maximum likelihood methods are more in vogue in secondary data analysis in sociology, the very large size of the datasets involved and the low rates of missingness of key variables made hotdecking, which is a
computationally more efficient imputation method, an attractive option for this study. 

Ten simulations were conducted on each imputed dataset for a total of 100 simulations.\textsuperscript{30}

Calculating genetic compatibility probabilities. One may have the same alleles at a locus in the genome with another through one of two mechanisms. First, as a result of basic processes of genetic descent one is guaranteed to share at least one gene at each locus in the genome with each of one’s parents at birth because parents’ genes combine to constitute one’s own genome. By extension, other genetic relatives who may be reached through parent-child network ties have a defined baseline probability of matching one’s genes at each locus in the genome. This form of genetic similarity is known as identity by descent (IBD) and is easily mathematically specifiable. For instance, one has a 50% chance of sharing a particular copy of a gene IBD with one’s sibling, a 25% of doing so with one’s half sibling, and so on. However, one may also share genes with related and unrelated alters through a process directly related to the population distribution of genes at each locus. For instance, if a gene does not vary at all in a population, one is guaranteed to match on this gene with all others in that population, and if 75% of all members of that population have the same allele one has an excellent chance of matching unrelated strangers on that gene, as well. This is known as identity by state (IBS). Both forms of genetic matching are important when predicting the availability of suitable living donors in one’s kinship network.

This stage of the analysis requires the assumption that, conditional on race, the ABO and HLA distributions of kidney transplant candidates are representative of the

\textsuperscript{30} Although additional simulations would be preferable, the very large memory requirements of this study and the computational intensiveness of the simulation limited the number of simulations which were feasible for this study. Additionally, as discussed below the distribution of simulated characteristics was very tight in this study, suggesting that additional simulations would not substantively change the primary results of this investigation.
general population, and that all families are racially homogenous. Under this assumption, the probability that a member of one’s kinship network has a compatible blood type with the transplant candidate may be calculated as follows (Kanter and Hodge 1990):

\[
P(C_{ijk}) = T_{2ijk} + T_{1ijk} q_k + T_{0ijk} q_k^2
\]  

(1)

where \(P(C_{ijk})\) is the probability of blood type compatibility, \(i\) indexes ego, \(j\) indexes alter, and \(k\) indexes racial/ethnic group. \(T_{xijk}\) is defined as the probability of sharing \(x\) alleles IBD at the ABO locus for a dyad with the \(i\)-\(j\) pair’s genetic relationship degree. Parent-child relations necessarily share exactly 1 allele at a locus due to common inheritance, so for these relations \(T_1=1\) and \(T_2=T_0=0\). For all other relationship types, the \(T\) values may be calculated by taking the average genetic relationship, \(r\), for that genetic relationship type\(^{31}\), and calculating \(T_2=r^2\), \(T_1=r(1-r)\), and \(T_0=(1-r)^2\). Finally, \(q_k\) is defined as the percentage of the racial/ethnic group that has a compatible blood type with \(i\)’s ABO phenotype, as measured in the ABO distribution among transplant candidates in the UNOS dataset. This component of the formula represents the probability of IBS matching. Blood type compatibility (as used in the \(q_k\) values) is defined as follows:

\[
\begin{array}{cccc}
A & B & AB & O \\
\hline
A & 1 & 0 & 0 & 1 \\
B & 0 & 1 & 0 & 1 \\
AB & 1 & 1 & 1 & 1 \\
O & 0 & 0 & 0 & 1 \\
\end{array}
\]

(2)

where recipient blood type is on the rows, donor blood type is on the columns, and blood type compatibility is defined as the matrix equaling 1 for the \(i,j\) cell of the compatibility matrix. Thus \(O\) is the universal donor, \(AB\) is the universal recipient, and otherwise all blood types are compatible with themselves.

\(^{31}\) \(r=.5\) for full siblings, \(r=.25\) for half siblings, grandparents, grandchildren, aunts, uncles, nieces, and nephews, \(r=.125\) for first cousins and similarly distant relations, and \(r=0\) for alters who are not genetically related
A similar procedure is used to calculate HLA compatibility probabilities, but this
calculation is necessarily more complicated because of the greater polymorphism at these
loci and the fact that there are three such genes under consideration instead of one. To
calculate HLA compatibility probabilities, the proportion of HLA haplotypes which are
compatible with a given haplotype on one, two, or three loci was calculated and added to
the following formulas:

\[ P(M_{ik} = 0) = T_0 q_{1k}^0 q_{2k}^0 \]

\[ P(M_{ik} = 1) = T_0 (q_{1k}^1 q_{2k}^0 + q_{1k}^0 q_{2k}^1) \]

\[ P(M_{ik} = 2) = T_0 (q_{1k}^2 q_{2k}^0 + q_{1k}^0 q_{2k}^2 + q_{1k}^1 q_{2k}^1) \]

\[ P(M_{ik} = 3) = T_1 q_{yk}^0 + T_0 (q_{1k}^1 q_{2k}^1 + q_{1k}^0 q_{2k}^2) \]

\[ P(M_{ik} = 4) = T_1 q_{yk}^1 + T_0 (q_{1k}^3 q_{2k}^1 + q_{1k}^1 q_{2k}^3 + q_{1k}^2 q_{2k}^2) \]

\[ P(M_{ik} = 5) = T_1 q_{yk}^2 + T_0 (q_{1k}^3 q_{2k}^2 + q_{1k}^2 q_{2k}^3) \]

\[ P(M_{ik} = 6) = T_2 + T_1 q_{yk}^3 + T_0 q_{1k}^3 q_{2k}^3 \]

where \( M_{ik} \) is defined as the HLA match degree (out of 6) for person \( i \) in race \( k \), \( q_{1k}^x \) and
\( q_{2k}^x \) are defined as the probability of \( x \) matches with an unrelated member of race \( k \) for
haplotypes 1 and 2 respectively, and \( q_{yk}^x \) is the probability of \( x \) matches for a randomly
chosen haplotype with an unrelated member of race \( k \). As with the simpler ABO formula
above, these formulas are designed to combine the ways in which a given match degree
can be attained through two different routes – IBD matching (represented by the \( T_x \)
components) and IBS matching (represented by the \( q \) components). For these
calculations, HLA compatibility was defined using the current list of HLA serological equivalencies\textsuperscript{32}.

*Calculating positive antigen crossmatch probabilities.* PRA is measured as the percentage of a representative set of HLA antigens to which the intended recipient’s blood displays an immunological reaction, indicating antibodies for the antigens in question. However, by definition one cannot be crossmatched with antigens serologically equivalent to one’s own, so the probability of a positive crossmatch is inversely proportionate to one’s HLA match degree with the alter in question. Allowing for this, the probability of positive crossmatch is calculated as:

\[
P(XM) = PRA \left( \frac{6 - M_{ik}}{6} \right)
\]  

(4)

where XM stands for crossmatch, \(M_{ik}\) represents the simulated number of HLA equivalencies, and \(6-M_{ik}\) indicates the number of mismatched HLA antigens with that donor pair. In other words, a transplant candidate’s PRA is adjusted to reflect the probability of crossmatch among the mismatched HLA antigens only.

**Information on Kinship Structures**

In order to predict the LDKT opportunity structure for transplant candidates in the U.S., information is employed on the distribution of genetically-defined kinship ties for demographically similar individuals in the U.S. It is important to define these kinship ties genetically rather than socially because genetic compatibility is a crucial determinant of donor suitability.

*Dataset: Panel Study of Income Dynamics Family Information Mapping System.*

It is equally crucial to define candidates’ kinship structure as broadly as possible. The

\textsuperscript{32} This is available for inspection at [http://optn.transplant.hrsa.gov/policiesAndBylaws/policies.asp. Accessed 8/21/2010.]
Panel Study of Income Dynamics (PSID) is one of the premier longitudinal studies of families in the U.S. In 1968 the PSID began following a representative sample of about 4,800 households. Subsequently the PSID re-interviewed the original families frequently (every year through 1997; every other year thereafter) and followed descendant families as households split and were formed. As such the PSID includes a strong genealogical component, as much of this household formation consisted of children growing up, moving out of the house, and forming families of their own. Some lineages now include as many as four generations.

Helpfully, the PSID now provides biologically-informed linkage files, known as the Family Identification Mapping System (FIMS), by which parent/child and sibling ties are defined among all members of the PSID sample. FIMS differentiates between biological and adoptive ties as well as permitting differentiation between full, half, and step-siblings. As such the PSID is now the premier source of population representative, longitudinal information on multigenerational black and white families in the U.S.

For the present analysis all members of the PSID who were alive in 1999 and had at least one measured biological kin tie were included in the analysis. Persons who died before 1999 were included when defining biological kinship networks but excluded thereafter. Each included person was assigned a biologically-informed ego kinship network as described below.

While Latinos are included in the sampling design as well, over time with high rates of Latin American migration into the U.S. the Latino sample became increasingly unrepresentative of the U.S. Latino population. While the PSID has since supplemented the original sample with additional Latino families, the later date of this sampling procedure means that information is available on fewer generations of these families, and would not permit a valid comparison of the kinship structure of Latinos with whites and African Americans. As such only white and black families are examined in this study. Additionally, the PSID sample design does not permit the identification of kinship linkages among those not directly descended from the originally sampled households through procreation, adoption, marriage, or co-residence. This is a major limitation of this dataset for present purposes because this means that key members of one’s kinship networks are excluded.
Characterizing kinship ties. Parental ties may be defined as $P_{N \times N}$, where $P_{ij} = 1$ if the individual on column $j$ is the parent of the individual on row $i$ and $=0$ otherwise. This matrix is non-symmetrical because one is not one’s parents’ parent. Similarly, full sibling ties may be defined as $FS_{N \times N}$, where $FS_{ij} = 1$ if the individual on column $j$ is the sibling of the individual on row $i$ and $=0$ otherwise. Of course, this matrix is symmetrical. Using these matrices only and adapting the formulas in Batagelj and Mrvar (2006; see Goldstein 1999 for a similar approach), biological kin relations may be calculated in matrix terms as follows (where $X'$ is defined as the transpose of matrix $X$):

- **Child**: $C = P'$

- **Half sibling**: $HS^* = 1$ if $P^*P' = 1$ and $=0$ otherwise

- **Grandparents**: $GP = P^*P$

- **Grandchildren**: $GC = P^*P'$

- **Aunt/Uncle**: $AU = P^*FS$

- **Niece/Nephew**: $NN = AU'$, where child ties are set to 0.

- **Cousin**: $P^*P^*P'^*P'$, where the resultant diagonal is set to 0.

Non-biological kinship ties are defined as the absence of any of these ties within a lineage.

Information on Health Statuses

In addition to genetic match degree and positive HLA antigen crossmatches, another reason a member of an ESRD patient’s kinship network may not be a suitable living kidney donor is due to a health condition which would endanger the kidney donor or recipient should an LDKT take place. These conditions are known as contraindications for kidney donation. Although there is no uniform standard for medical evaluations of
LDKTs, in 2007 an OPTN committee made a set of recommendations for ‘absolute’ and ‘relative’ contraindications for living kidney donation based on a survey of nephrologists’ evaluation practices. The list of ‘absolute’ contraindications include: age less than 18 years old, hypertension, diabetes, abnormal glucose tolerance test, history of thrombosis or embolism, major psychiatric conditions, extreme obesity (BMI>35), coronary artery disease, symptomatic valvular disease, chronic lung disease, recent malignancies (or cancers with a long time to recurrence), urologic abnormalities of the kidney, low creatinine clearance rates, peripheral vascular disease, proteinuria, HIV infection, Hepatitis C infection, and Hepatitis B infection. Although some transplant centers surely deviate in various manners from this list, for present purposes insofar as possible this list of statuses and conditions is treated as the full list of contraindications for living kidney donation.

*Dataset: National Health and Nutrition Examination Surveys (NHANES) 1999-2008.* Collected since 1959, the NHANES studies have long served as the nation’s most detailed population representative survey of the health of the U.S. populace. In addition to household, socioeconomic and demographic information, NHANES collects a full medical history, detailed medical examination by a physician, and an impressive collection of laboratory measures assessing the prevalence of major chronic health conditions in the U.S. population. Since 1999, NHANES has been collected in consecutive two-year cycles, with data available for 1999-2000, 2001-2, 2003-4, 2005-6, and 2007-8.
**Medical contraindications.** Hypertension was defined as having an average blood pressure greater than 130/90 on average over four separately measurements\(^\text{34}\). Diabetes was measured as reporting ever being diagnosed with diabetes. Abnormal glucose tolerance was defined as a 2-hour glucose tolerance test score greater than 140. Psychiatric conditions were defined using survey-based measures of panic disorder, major depression, and generalized anxiety disorder. Although survey-based measures are not ideal measurements of psychiatric conditions, the measures used were well-validated measures of DSM-defined criteria. Furthermore, this is not an exhaustive list of potentially disqualifying psychiatric conditions; however, these were the only ones available in the NHANES data.

Obesity was assessed as a calculated BMI score greater than 35\(^\text{35}\). Coronary artery disease was based on respondent reports of previous diagnoses of coronary artery disease. Chronic lung disease was assessed by having ever been diagnosed with asthma, emphysema, or having current bronchitis. Cancer history excludes one from kidney donation if one has ever had breast cancer or had any cancer in the last ten years. Creatinine clearance rates (eCCR) were assessed using the Cockcroft-Gault formula for estimated creatinine clearance rates (Cockcroft and Gault 1976), and poor kidney function was defined as eCCR<80.

Peripheral artery disease was defined as having a right or left ankle-brachial index score (Hirsch et al. 2006) of less than 0.9 (Criqui and Denenberg 1998). Proteinuria was measured as having an albumin-creatinine ratio of ≥17 for men and ≥25 for women

---

\(^{34}\) While this is not the standard cutoff for hypertension, this is the recommended cutoff for evaluating blood pressure as a contraindication for living kidney donation.

\(^{35}\) Similarly, although BMI of 30 is the standard research cutoff for obesity, a BMI of 35 is the cutoff recommended by the OPTN committee.
HIV diagnoses were based on HIV antibodies in the respondent’s blood (McQuillan et al. 2010). Hepatitis B diagnoses were based on the result of a hepatitis B surface antigen test (Ioannou 2011), and hepatitis C diagnoses were based on the results of a hepatitis C antibody test (Armstrong et al. 2006).

Measures were not available in NHANES 1999-2008 for history of thrombosis or embolism, symptomatic valvular disease, or urologic kidney abnormalities. Furthermore, all measures used in this analysis were not available in all years and were not always available for the full sample or persons of all ages. The following steps were taken to address these data limitations. First, if data were not available for all years of NHANES data, the same demographic patterns of that contraindication were assumed for all years. Second, HIV, Hepatitis B, and Hepatitis C, and all psychiatric measures were not available for NHANES respondents over 50. This analysis assumes that the prevalences of these diseases for persons aged 51 and older are the same as for persons aged 36-50. Finally, measures of peripheral artery disease were not available for persons younger than 35. This analysis assumes that this prevalence is 0.

**Combining Information on Transplant Candidates, Kinship Structures, and Population Health Distributions**

For this simulation, information on kinship structure and kinship health statuses was assigned in two steps. First, medical contraindications were assigned to members of measured kinship networks proportionate to the probability of having a medical contraindication among demographically similar members of the health status dataset. Second, kinship networks and health statuses were assigned to transplant waitlist members using an original weighted matching algorithm designed by the author.
For the purposes of this study all variables measuring medical contraindications for living kidney donation in NHANES were combined into a single indicator for medical contraindications and probabilistically assigned to members of the PSID based on the weighted proportion of persons with any contraindication in that person’s race, age, education, and gender categories. Race was defined as being either white or black, by self-report. For matching purposes age was coarsened into the following categories: age 0-20, 21-35, 36-50, 51-65, and 66+. Education was recoded into the following categories: less than a high school education, high school education or equivalent, some college courses but no four-year degree, and a four-year college degree or higher. Gender was measured as being either male or female. When members of the PSID dataset were missing information on any of these variables, contraindications were assigned proportionate to demographic categories on which the respondent had complete information only. After probabilities of having a contraindication were assigned to all members of the PSID, their contraindication status was determined by comparing the value of a uniform random variable to their assigned probability of having any of the measured medical contraindications.

Assigning Kinship Networks to Transplant Candidates

Individuals’ kinship structures are strongly related to age, and somewhat less so, race, education, and gender. In the first case, one cannot be a grandparent if one is 10 years old and is unlikely to have a living parent if one is 90 years old. Similarly, due to fertility and mortality differences by race and education, kinship structure will be related to these factors as well. Although based on available data one cannot know the kinship structures of persons on the kidney transplant waiting list, one can probabilistically
reproduce the distribution of measured kinship ties in PSID interactively by age, race, education, and gender, recoded as described above.

Kinship network assignment was conducted based on a weighted matching algorithm designed by the author, which functions as follows (and is illustrated in Figure 3). First, members of the kidney transplant waitlist and the PSID were assigned groups for all combinations of race, education, gender, and age. This assignment was identical for both datasets. Second, individual sampling weights in the PSID were transformed as follows:

\[ w'_{ik} = \frac{w_{ik}}{\sum_{l=1}^{n} w_{lk}} \]  

(6)

In other words, individual weights were transformed into the proportion of total individual weights represented in group k. Thus the transformed weights all summed to one within each of the demographic groups observed. Third, the \( w'_{ik} \) values were transformed so that each individual was assigned a range of the 0-1 probability space equal to their value of \( w'_{ik} \). Fourth, individuals on the kidney transplant waitlist were each assigned a uniform random variable \~U(0,1), which was compared to the values of this transformed weight variable so that kidney transplant candidates were assigned kinship networks for persons with identical demographic characteristics proportionate to their weights using a many-to-one matching algorithm.

To aid the reader in understanding this unfamiliar method, Figure 3 illustrates this process in simplified form. In this figure, ten hypothetical members of the kidney transplant waiting list are shown in the spreadsheet to the left, and 20 members of the PSID (two of which have identical demographic characteristics as each of the waitlisted persons) are depicted to the right. In addition to the demographic characteristics, a weight
column and range column are assigned to the observations in the hypothetical PSID spreadsheet. The weight column is $w'_{ik}$, and the range column is the transformed version of this variable described above, constructed so that each PSID sample member is assigned a probability space equal to their value of $w'_{ik}$. Because more than one PSID sample member matches the characteristics of each transplant waiting list member, these range values are used to assign kinship networks for demographically identical persons in the PSID proportionally to such persons’ share of the target population of the PSID. The $u$ column in the waiting list spreadsheet is used to determine which kinship network is actually assigned, and rows which are assigned to waiting list members are highlighted in gray in the spreadsheet on the right, with arrows linking the merged observations. So, for instance, observation 1 in the waiting list spreadsheet in this illustration is assigned the kinship network of observation 1 in the PSID spreadsheet because their value of $u$ was between 0 and 0.4, the range associated with that member of the PSID, and the observations otherwise match on demographic characteristics. If this person’s $u$ value had been 0.7 instead, the kinship network of observation 2 would have been assigned to them.

The virtue of this approach is to assign kinship networks to members of the kidney transplant waitlist based on one’s kinship-relevant demographic characteristics, and also assigns kinship network directly proportionally to the sampling weights associated with the PSID observation in question. While imperfect, this procedure assigns observed kinship networks in a manner which preserves the association of demographic characteristics with kinship structure and maintains the population representativeness of the kinship distributions conditional on these demographic characteristics.

**Calculating the Opportunity Structure Distribution**
The procedures just described were used to assign kinship structures to transplant candidates, and probabilities of HLA and ABO histocompatibility, positive crossmatch, and medical contraindications to kinship network alters. These are the full list of proximate determinants of LDKT opportunity structure. As a final step, the joint distribution of these properties was calculated for each transplant candidate to generate a distribution of suitable living kidney donor ties within each assigned network. Each kin that meets the following conditions was counted as a suitable living kidney donor: a) ABO histocompatibility, b) two or more HLA matches, c) no positive crossmatch, d) no medical contraindication, and e) the kin is 18 years old or above.

Using this calculation, each transplant candidate was assigned the number of kin that meet these transplant suitability conditions, and also a dichotomous variable measuring whether they had any suitable donors in their kinship network. These were the primary dependent variables of the present analysis. Additionally, the distribution of living kidney donor suitability, and reasons for exclusion if not suitable, were preserved for each kin in the patient’s kinship network.

Calculating Counterfactual Effects

The procedures just described are sufficient, contingent on the assumptions of the simulation, to estimate the LDKT opportunity structure for whites and blacks on the kidney transplant waitlist. However, because these characteristics are jointly simulated, the role of each factor in producing differential LDKT opportunity structures will not be clear. To address this shortcoming, a series of counterfactual microsimulations were produced for each simulation run, in which the distributions of each proximate determinant of the LDKT opportunity structure (ABO and HLA match, PRA, kinship
structure, and medical contraindications) are redistributed at random across all kidney transplant candidates and then re-simulated.

Blacks and whites in the different datasets employed here enter the simulation with different distributions of the proximate determinants of the LDKT opportunity structure. By re-assigning these characteristics at random from the original distribution, irrespective of the other characteristics of the observed person, LDKT opportunity structures may be estimated in the absence of the baseline differences in these characteristics. The estimated effect of the distributional differences in the proximate determinant is then calculated as:

$$
\beta_X = 100 \left\{ \frac{[(Y_{1X} - Y_{2X}) - (Y_{1B} - Y_{2B})]}{(Y_{1B} - Y_{2B})} \right\}
$$

(7)

where $\beta_X$ is the estimated percentage of the racial gap in LDKT opportunity structures explained, $Y_{1B}$ and $Y_{2B}$ are the median simulated values of the dependent variable in the non-counterfactual (baseline) simulation for races 1 and 2 respectively (where the group with the higher median value of the dependent variable is substituted into $Y_{1B}$), and $Y_{1X}$ and $Y_{2X}$ are the same median simulated values of the dependent variable when counterfactual simulations for X are conducted.

The resultant value from this calculation may be interpreted as the percentage of the baseline simulation difference in the dependent variable explained by equalizing variable X. If $\beta_X = 50$, for instance, this means that the racial gap in the dependent variable is 50% smaller in the counterfactual condition than in the baseline simulation, suggesting that the group with the lower baseline median value of Y is disadvantaged by characteristic X. Additionally, $\beta_X$ may take on negative values or values greater than 100. In the former case, this is interpreted to mean that equalizing this factor increases the
simulated difference in the dependent variable by race, suggesting that the group with the lower median value of Y derived some advantage from racial differences in X. In the latter case, $\beta_X > 100$ suggests that, not only is characteristics X a source of disadvantage for race 2, but that equalizing it would result in the disadvantaged group having an overall advantage in Y.

**Results**

**Kidney Transplant Waitlist: Descriptive Statistics**

Table 1 presents descriptive statistics on the demographic composition of the U.S. population based on American Community Survey estimates 2001-2009 (Ruggles et al. 2010), the same figures on the composition of the kidney transplant waitlist from July 1, 2000 through February 26, 2010, and the ratio of their representations. All figures are subsetted to include only white and black persons. The ratio column crudely measures the degree to which members of that demographic group are over- or under-represented on the kidney transplant waitlist during this time relative to their share of the population. Finally, the distribution of PRA for each group is presented.

The results of the ACS-UNOS demographic comparisons reveal the degree to which members of the American populace are overrepresented on the kidney transplant waitlist. Young persons are much less common than older persons to be on the kidney transplant waitlist, and persons aged 36-65 are much more likely to be on the waitlist. Educational patterns are also revealing – although those with less than a high school education are less likely than others to be on the waitlist, this is likely due to the association of this educational attainment with younger ages. For all other educational categories, higher education is associated with lower rates of transplantation waitlisted.
Additionally, males are much more likely than females to be on the transplant waitlist. Finally, African Americans are greatly overrepresented on the transplant waitlist – approximately 2.57 times more likely to be on the waitlist than their representation in the population.

Table 1 also reveals appreciable demographic patterns of PRA among those on the kidney transplant waitlist. While the average PRA score is .175, patients aged 51-65, less educated persons, women, and African Americans have substantially higher PRA scores on average than their age, education, gender, and racial counterparts. The remainder of this section is organized around a series of questions the present analyses are designed to answer.

**Could Patterns of Medical Contraindications Explain Racial Differences in LDKT?**

Table 2 presents the demographic distribution of contraindications for living kidney donation, as estimated using NHANES 1999-2008 data. The ‘All’ column describes the joint distribution of contraindications and the remaining columns describe their individual distribution. Age exclusions are represented in the ‘All’ column only. According to these estimates, 77.5% of whites and 81.6% of blacks are excluded from living kidney donation for medical or demographic reasons. These results suggest health condition disadvantages for African Americans when pursuing an LDKT.

However, the results also show substantial variability in the racial patterns of medical exclusions. African Americans have higher prevalences of hypertension, diabetes, obesity, albuminuria, hepatitis B, hepatitis C, and HIV than whites. However, whites are subject to higher prevalences of abnormal glucose tolerance, psychiatric disorders, coronary artery disease, chronic lung disease, cancer, low creatinine clearance
rate, and peripheral artery disease exclusions. On balance the joint distribution of these characteristics produce a moderate disadvantage for African Americans when pursuing an LDKT.

**Could Race Differences in Kinship Structure Explain Racial Differences in LDKT?**

Table 3 presents the distribution of biologically-informed kinship ties, as assigned to members of the kidney transplant waitlist using the weighted matching algorithm described above. These results suggest that African Americans on the kidney transplant waiting list are likely to have larger kinship networks on average as well as greater variability in their distribution of kinship ties. Furthermore, this difference holds for every measured kinship type. Together, these results indicate that the LDKT opportunity structures of African Americans are advantaged by the overall size of their networks and the number of close genetic relatives therein.

**Could Race Differences in Histocompatibility Probabilities Explain Racial Differences in LDKT?**

Table 4 presents the distribution of ABO and HLA histocompatibility by race and genetic relationship with alters of the same race, calculated as described above. For members of both races, the probability of ABO histocompatibility is higher for close genetic relatives than for more distant genetic relatives and unrelated alters. However, the probability of ABO histocompatibility is moderately high (>40%) for even unrelated alters of both races. This analysis also shows evidence that the probability of ABO histocompatibility is slightly higher for whites than for blacks for all genetic relationship types, and this race difference grows with decreasing genetic relationships with the alters in question. So, for instance, the probability that a white person is ABO compatible with
their full sibling is only 2% higher for whites than for blacks, but this difference is 4.2% for unrelated alters.

Similar patterns are observed for probabilities of HLA histocompatibility degree. For members of both races, parents and full siblings offer the best chance for a strong HLA match degree. Parents are guaranteed to share three or more HLA alleles with their children, but the marginal probability of additional matches beyond three decreases rapidly. In contrast, full siblings have a moderately high chance (approximately 25%) of being a full HLA match with one another. On the other end of the genetic relationship spectrum, unrelated alters have greater than a 50% of having no HLA matches with the transplant candidate, reflecting the high degree of polymorphism in the HLA-\(A\), -\(B\), and –\(DR\) loci.

These calculations also reveal that whites are more likely to have a high degree of HLA match with their kinship alters conditional on genetic relationships, and that this difference grows with declining genetic relationships with the alters. Altogether, these results demonstrate that whites have a higher probability of genetic histocompatibility with given members of their kinship network conditional on genetic relationship with that alter.

**How do Kinship Structure, Health Patterns, and Histocompatibility Probabilities Jointly Shape the LDKT Opportunity Structure by Race?**

Table 5 presents the simulated distribution of suitable living donors, as defined above. The results suggest that whites are actually somewhat less likely to have at least one suitable living donor in their kinship networks than are blacks. 58.2% of white ESRD patients are simulated to have a suitable living kidney donor in their kinship network, whereas this is true of 62.5% of black ESRD patients. Furthermore, among those
simulated to have a suitable donor in their network, blacks on average are simulated to have more such donors than are whites.

The results also illustrate racial differences in this difference by genetic relationship type. For instance, whites are slightly more likely to have a suitable sibling or child living kidney donor whereas blacks are more likely to have at least one suitable such donor in all other genetic relationship categories. Children are the relationship category in which patients are most likely to have a suitable donor, followed, surprisingly, by non-biological kin. This latter effect is a result of the fact that most kinship networks have a very large number of kin with no defined biological tie to the reference person.

Taken together, these results suggest that African American patients on the kidney transplantation waitlist are more likely to have a suitable living kidney donor in their kinship network, and more likely to have more than one such suitable donor, than are white persons.

**What is the Probability that Each Member of One’s Kinship Network Will Be a Suitable Living Kidney Donor?**

While Table 5 presented the distribution of suitable living donors from the waitlisted patient’s perspective, Table 6 describes the probability that each individual member of one’s kinship network will be a suitable living donor, stratified by race and genetic relationship type. Table 6 also provides the probabilities of living donor exclusions for HLA histocompatibility, ABO histocompatibility, medical or age contraindication, or positive crossmatch reasons. (These outcomes do not add up to 100% because a donor can be excluded for more than one reason.)
These results suggest that a random member of a white person’s kinship network is more likely to be a suitable living donor than a random member of a black person’s kinship network. On average, 6.4% of white kinship alters are simulated to be a suitable living donor, while this is true for only 5.4% of black kinship alters. Black kinship alters are more likely than white kinship alters to be excluded for HLA, ABO, medical contraindication, and positive crossmatch reasons.

These results also suggest considerable variability in the probability that a given kinship alter will be a suitable living donor by genetic relationship. Whites’ full siblings, parents, children, grandchildren, aunts, uncles, first cousins, and unrelated kin are more likely than comparable black alters to be a suitable living donor, whereas black half siblings are more likely than whites’ half siblings to be an appropriate living donor. Finally, the probability of living donor suitability varies proportionately with the genetic relationship degree – full siblings, children, and parents are the most likely suitable living donors, whereas non-biological kin have a very low probability of being a suitable living donor.

What are the Contributions of Genetics, Kinship Structure, Health, and PRA to Racial Differences in LDKT Opportunity Structures?

To answer this question, counterfactual microsimulations were estimated in which each of four factors – genetic distributions, kinship structures, health statuses, and PRA – were re-assigned to the appropriate individuals at random while preserving their overall distributions. The results of this exercise confirm the findings of the previous analyses (Table 7). Genetics are a source of LDKT opportunity structure for whites – equalizing the probability of genetic match degree results in a 14.5% increase in black opportunity structure advantage in the proportion of patients with suitable living donors in their
kinship network, as well as a 40.6% increase in their advantage in the average number of suitable living donors. Health distributions are a very small source of white advantage, and equalizing this factor adds only .8% and 1.5% to the black advantage in the proportion with a suitable donor and the number of donors respectively. PRA differences by race are also a source of white advantage in the LDKT opportunity structure. Equalizing this factor results in an 18.7% increase in the black advantage in the proportion with suitable donors and a 20.4% increase in the average number of donors. Finally, all factors were equalized simultaneously to confirm that this equalizes the LDKT opportunity structure. It does – whites and blacks have equivalent LDKT opportunity structures when all four factors are equalized.

In summary, whites transplant candidates are on average expected to be advantaged in the LDKT opportunity structures by their higher probability of genetic histocompatibility, favorable health status, and lower probability of antigen crossmatch. In contrast, the African American advantage in the LDKT opportunity structure stems from their larger average kinship structures. Equalizing this factor gives whites on average a higher proportion of kinship structures including a suitable living donor and a higher average number of such donors than blacks.

**What Proportion of Suitable Living Donors Contribute Kidneys for Transplantation?**

As a crude analysis of the answer to this question, the proportion of white and black transplant candidates who actually obtained an LDKT transplant is compared to the proportion estimated to have a suitable donor in their kinship structure in Table 8. The results suggest that, conditional on having a suitable donor in one’s kinship structure, whites are more likely to obtain an LDKT than are blacks. Although a higher proportion
of black patients are estimated to have a suitable donor, they are less than half as likely to actually obtain an LDKT as are whites. Furthermore, the proportion of members of both races actually obtaining an LDKT is substantially lower than the proportion estimated to have a suitable donor in their network.

**Discussion**

This paper investigates racial differences in the opportunity for LDKT in the kinship structures of whites and blacks on the kidney transplant waitlist. By matching data on the distribution of kinship ties, medical contraindications for living kidney donation, the probability of HLA and ABO histocompatibility degrees, and the probability of positive crossmatches between candidates and kin, this research examines how kinship structures, health conditions, and genetic and immunological factors shape the opportunity for LDKT. If whites and blacks substantially differ in their LDKT opportunity structures, this could partially explain racial differences in LDKT rates.

The results show that this is not the case. If anything, blacks are likely to have suitable living kidney donors in their kinship structures at higher rates than whites, and have more such kin in their network conditional on having any. However, each individual white kin has a higher probability of being a suitable living donor than comparable black kin.

In light of research on the living donor search behaviors of kidney transplant candidates and their kin, however, these results suggest a mechanism by which LDKT opportunity structures could produce racial disparities in LDKT. According to one study, only about half of transplant candidates bring in any potential donors for evaluation, and of those who do so, the large majority bring in two or fewer potential donors (Weng et al.
2010). Furthermore, black potential donors are less likely to complete the evaluation process and are more likely to be excluded for medical, genetic, or immunological reasons, conforming to the patterns observed here. Therefore, because transplant candidates do not have their full social networks evaluated for donation, it may be that the probability that a given alter is a suitable donor is the more important determinant of LDKT outcomes than the number of suitable donors in one’s total network.

Additional factors which are hypothesized to moderate the relationship between LDKT opportunity structures and LDKTs may shed additional light on the causes of racial inequalities in LDKT. First, racial differences in kin relations could structure the probability that kin are evaluated for donation and proceed with donation conditional on a positive evaluation. Second, racial differences in beliefs concerning the appropriateness and benefits of LDKT could influence these differences. However, racial differences in the rates at which potential donors are evaluated for donation are minor (Weng et al. 2010) and are unlikely to play a major role in the explanation of these differences.

Racial differences in interactions with the health care system may also play a substantial role in the mediation of the effect of the LDKT opportunity structure on LDKT rates. If medical providers differentially promote and support living donor evaluation among whites and blacks, this could potentially explain racial differences in the rates at which donors are brought in for evaluation, complete evaluations, and donate kidneys conditional on positive evaluations. Racial differences in knowledge of transplantation could play a similar role in the mediation of this difference.

Many of the factors which can preclude kidney donation are subject to potential interventions. Progress in techniques to ameliorate the effects of positive crossmatching,
HLA mismatching, and the ABO barrier may affect racial differences in the LDKT opportunity structure in the future. Although none of these techniques offer candidate and graft survival rates equivalent to those for more ideal kidney donor-candidate combinations, should progress continue to be made on these fronts it may be that these may undermine racial differences in the LDKT opportunity structure.

Furthermore, many health conditions which preclude living kidney donation are linked to lifestyle and environmental differences which are potentially modifiable. For instance, diabetes, abnormal glucose tolerance, and obesity prevalences have been growing in the general population, particularly for African Americans, and are linked to quality of diet and exercise. Should these trends be reversed in an equitable fashion this could raise rates of LDKT and ameliorate racial inequalities therein.

The results of this analysis also suggest that white and black patients are underutilizing their LDKT opportunity structures, although blacks do so to a greater degree. In principle, these results suggest that rates of LDKT could be increased by a factor of three for whites and seven for blacks. While an increase on this scale is unlikely, this suggests that there is room for higher LDKT rates among whites and blacks, and that if whites and blacks searched throughout the entirety of their kinship networks, racial inequalities in LDKT could be eliminated or reversed.

Finally, efforts to increase the rate at which white and black transplant candidates search throughout their full kinship networks could serve to improve transplantation prospects for those without suitable living donors in their kinship networks. Because there is a shortage of kidneys compared to the kidney transplant waitlist, each additional LDKT implies a marginally improved transplant prospect for all others on the waitlist. Of
course, any efforts to increase the rate at which LDKT opportunity structures are converted into transplants should be conducted in a non-coercive manner.

This research is subject to a number of limitations, the foremost of which is that direct data on the kinship networks of kidney transplant candidates is unavailable except for those alters who actually donate kidneys. Although this study is conducted using high quality data on kidney transplant candidates and on the distribution of biologically-informed kinship ties by race and patterns of relevant health conditions, the simulations discussed here require a number of strong assumptions. The most important of these assumptions are that: a) conditional on race, kidney transplant candidates ABO and HLA genes are representative of the population; b) conditional on race, age, education, and gender, members of the kidney transplant waitlist are subject to similar distributions of kinship ties to that of the general population; and c) conditional on race, age, education, and gender, the kin of members of the kidney transplant waitlist are subject to identical probabilities of medical contraindications to that of the general population. The degree to which these assumptions are consequentially violated should be a subject of future research.

**Conclusion**

This paper reports on a simulation analysis of the distribution of suitable living kidney donors in the kinship networks of white and black kidney transplant candidates.

The goal was to investigate the possibility that racial differences in the availability of kin donors could be...
who would be suitable kidney donors could explain racial differences in LDKT rates. To the contrary, however, the results of the analysis suggest that blacks and whites have approximately the same probability of having a suitable living donor in their kinship network, although the probability that an individual member of the kinship network is a suitable living donor is somewhat higher for whites than for blacks. While white kidney transplant candidates are advantaged by their higher probabilities of genetic similarity with their kin, their lower probabilities of positive crossmatching therewith, and slightly advantaged in the health characteristics of their kin, the larger typical size of black kinship networks ameliorates this advantage.

Demographers and sociologists have much to contribute to the understanding of racial inequalities in kidney transplantation. Racial differences in kinship structures, kin relations, interactions with medical care providers, beliefs and knowledge concerning transplantation, and genetic and immunological factors may go far in explaining racial disparities in deceased and living donor kidney transplantation. Social scientists know much about these topics. Although the present results do not explain racial differences in LDKT directly, they do suggest a major role for well-studied social processes in the production of these disparities. By engaging with medical researchers in the analysis of this important and growing problem, social science can do much to improve understanding of racial disparities in kidney disease and transplantation.
References


Gordon, E. J. 2001. ""They don't have to suffer for me": Why dialysis patients refuse offers of living donor kidneys." Medical Anthropology Quarterly 15:245-267.


### Tables and Figures

#### Table 4.1: US Population and Kidney Transplant Waitlist Characteristics, 2000-2010

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<tr>
<th>Variable</th>
<th>Category</th>
<th>ACS</th>
<th>UNOS</th>
<th>Ratio</th>
<th>PRA</th>
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<td>Overall</td>
<td>--</td>
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</tbody>
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NOTE: PRA means ‘Panel Reactive Antibody,’ a measure of immunological presensitization scaled 0-1, representing the proportion of the US populace for whose HLA antigens one’s immune system has already generated antibodies. ACS figures are weighted percentages in these categories in the 2001-2009 American Community Survey IPUMS 1% samples among blacks and whites only. UNOS figures are percentages in these categories on the UNOS waitlist 7/1/2000 through 2/26/2010 among blacks and whites only. Ratio is the ratio of the UNOS percentage divided by the ACS percentage and is interpreted as a measure of the degree to which this category is over- or under-represented on the kidney transplantation waitlist relative to its share of the population.
Table 4.2: Percentage Distribution of Contraindications by Demographic Categories and Contraindication Type

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Contraindications</th>
<th>All</th>
<th>HYP</th>
<th>DIAB</th>
<th>GLTT</th>
<th>PSYC</th>
<th>OBES</th>
<th>COAR</th>
<th>CHLD</th>
<th>CANC</th>
<th>CRCL</th>
<th>PARD</th>
<th>ALBM</th>
<th>HEP</th>
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<td>6.73</td>
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<td>10.56</td>
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<td>8.78</td>
<td>12.93</td>
<td>0.11</td>
<td>8.24</td>
<td>1.25</td>
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<td>0.05</td>
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<td>6.88</td>
<td>16.76</td>
<td>16.44</td>
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<td>9.62</td>
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<td>77.95</td>
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<td>17.52</td>
<td>26.61</td>
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<td>17.39</td>
<td>6.13</td>
<td>11.80</td>
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<td>21.65</td>
<td>5.95</td>
<td>0.63</td>
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<td>49.44</td>
<td>17.96</td>
<td>8.71</td>
<td>12.30</td>
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<td>71.54</td>
<td>15.18</td>
<td>0.74</td>
<td>4.29</td>
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</table>

NOTE: Figures in cells are shown as percentages. The following abbreviations for kidney donation contraindications are used: HYP: hypertension; DIAB: diabetes; GLTT: glucose tolerance test; PSYC: psychiatric disorders; OBES: obesity; COAR: coronary artery disease; CHLD: chronic lung disease; CANC: cancer; CRCL: creatinine clearance; PARD: peripheral artery disease; ALBM: albuminuria; HEP: Hepatitis B, C, or HIV. See Appendix ___ for the measures and cutoffs used to define each contraindication in this study. The following abbreviations are used for educational categories: <HS: less than high school; HS: high school or GED; SC: some college but no four year degree; BA+: four year college degree or more.
Table 4.3: Measured Biological Kinship Tie Distribution, by Race

<table>
<thead>
<tr>
<th>Kinship Type</th>
<th>WHITEs</th>
<th></th>
<th>BLACKs</th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Mean</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td></td>
<td>Median 90% Interval</td>
<td>Median 90% Interval</td>
<td>Median 90% Interval</td>
<td>Median 90% Interval</td>
</tr>
<tr>
<td>Full Siblings</td>
<td>0.63 (0.61,0.65)</td>
<td>1.32 (1.30,1.34)</td>
<td>0.75 (0.72,0.81)</td>
<td>1.88 (1.81,1.94)</td>
</tr>
<tr>
<td>Half Siblings</td>
<td>0.22 (0.21,0.22)</td>
<td>0.80 (0.78,0.81)</td>
<td>0.73 (0.70,0.80)</td>
<td>1.73 (1.68,1.82)</td>
</tr>
<tr>
<td>Parents</td>
<td>0.66 (0.65,0.70)</td>
<td>0.89 (0.88,0.90)</td>
<td>0.69 (0.67,0.72)</td>
<td>0.82 (0.82,0.83)</td>
</tr>
<tr>
<td>Children</td>
<td>1.91 (1.84,1.93)</td>
<td>1.43 (1.42,1.45)</td>
<td>2.23 (2.17,2.26)</td>
<td>1.88 (1.86,1.95)</td>
</tr>
<tr>
<td>Grandparents</td>
<td>0.14 (0.13,0.20)</td>
<td>0.47 (0.46,0.57)</td>
<td>0.18 (0.16,0.23)</td>
<td>0.49 (0.47,0.56)</td>
</tr>
<tr>
<td>Grandchildren</td>
<td>1.59 (1.51,1.66)</td>
<td>2.75 (2.69,2.81)</td>
<td>2.09 (1.97,2.17)</td>
<td>3.34 (3.25,3.42)</td>
</tr>
<tr>
<td>Aunts/Uncles</td>
<td>0.12 (0.11,0.19)</td>
<td>0.65 (0.63,0.82)</td>
<td>0.17 (0.15,0.25)</td>
<td>1.00 (0.93,1.19)</td>
</tr>
<tr>
<td>Nieces/Nephews</td>
<td>0.95 (0.89,0.97)</td>
<td>2.59 (2.52,2.63)</td>
<td>1.07 (0.98,1.16)</td>
<td>3.05 (2.92,3.16)</td>
</tr>
<tr>
<td>1st Cousins</td>
<td>0.28 (0.27,0.45)</td>
<td>1.53 (1.48,1.89)</td>
<td>0.67 (0.61,0.91)</td>
<td>2.77 (2.61,3.21)</td>
</tr>
<tr>
<td>Non-Biological Kin</td>
<td>13.58 (13.46,13.69)</td>
<td>13.83 (13.72,13.97)</td>
<td>19.32 (19.08,19.70)</td>
<td>18.62 (18.43,18.84)</td>
</tr>
</tbody>
</table>

NOTE: Standard deviation columns indicate the average within-group standard deviation in the number of indicated kinship ties. 90% Interval columns indicate the 5th and 95th percentiles of these values across simulations.
Table 4.4: Percentage Distribution of ABO Compatibility and HLA Match Degree by Race and Genetic Relationship

<table>
<thead>
<tr>
<th>Genetic Relationship</th>
<th>Race</th>
<th>ABO Compatible</th>
<th>HLA Matches (Out of 6)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
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<tr>
<td>Parent-Child</td>
<td>White</td>
<td>64.9</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>71.6</td>
<td>24.3</td>
<td>3.8</td>
</tr>
<tr>
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<td>Black</td>
<td>63.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>75.9</td>
<td>21.7</td>
<td>2.2</td>
</tr>
<tr>
<td>r=.500</td>
<td>White</td>
<td>68.8</td>
<td>12.8</td>
<td>8.8</td>
<td>2.8</td>
<td>36.4</td>
<td>12.2</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>66.8</td>
<td>14.4</td>
<td>8.2</td>
<td>2.0</td>
<td>38.3</td>
<td>10.9</td>
<td>1.1</td>
</tr>
<tr>
<td>r=.250</td>
<td>White</td>
<td>55.4</td>
<td>25.5</td>
<td>17.5</td>
<td>5.6</td>
<td>36.9</td>
<td>12.3</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>52.4</td>
<td>28.8</td>
<td>16.5</td>
<td>4.1</td>
<td>38.5</td>
<td>10.9</td>
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<td>26.3</td>
<td>8.5</td>
<td>19.6</td>
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<tr>
<td></td>
<td>Black</td>
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<td>43.3</td>
<td>24.7</td>
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<td>0.6</td>
</tr>
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<td>51.1</td>
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<td>2.3</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
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<td>8.1</td>
<td>1.1</td>
<td>0.1</td>
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</tr>
</tbody>
</table>

NOTE: HLA match percentages are gray scaled such that darker cells indicate higher match probabilities. ABO and HLA matches are defined as having alleles which are either identical or serologically equivalent to one’s alleles. Probabilities were calculated using genetic probability theory and the ABO and HLA-A, -B, and –DR distributions on the kidney transplantation waitlist – see text for details. No parents or children were excluded for HLA reasons because all parents and children share at least three HLA genes in common.
Table 4.5: Distribution of Simulated Donor Supply, by Race and Genetic Relationship

<table>
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<th>Genetic Relationship</th>
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<th></th>
<th></th>
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</thead>
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<td>(0)</td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
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<td>30.4</td>
<td>16.8</td>
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<td>3.7</td>
</tr>
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<td>0.1</td>
<td>0.0</td>
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<td>0.1</td>
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<td>4.1</td>
<td>1.2</td>
<td>0.4</td>
<td>0.1</td>
</tr>
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<td>White</td>
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<td>0.2</td>
<td>0.0</td>
<td>0.0</td>
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<td>0.5</td>
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<td>79.5</td>
<td>16.0</td>
<td>3.4</td>
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NOTE: Numbers in cells are expressed as percentages.
Table 4.6: Percentage Simulated Living Donor Evaluation Outcome, by Race and Genetic Relationship

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<th>Genetic Relationship</th>
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<td>ABO</td>
<td>Contraindication</td>
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<td>21.91</td>
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<td>White</td>
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<td>0.00</td>
<td>35.40</td>
<td>77.63</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>12.88</td>
<td>0.00</td>
<td>37.11</td>
<td>77.47</td>
</tr>
<tr>
<td>Children</td>
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<td>22.30</td>
<td>0.00</td>
<td>35.17</td>
<td>63.20</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>18.87</td>
<td>0.00</td>
<td>37.07</td>
<td>66.98</td>
</tr>
<tr>
<td>Grandparents</td>
<td>White</td>
<td>6.21</td>
<td>43.88</td>
<td>44.90</td>
<td>78.38</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>6.19</td>
<td>43.90</td>
<td>47.90</td>
<td>76.76</td>
</tr>
<tr>
<td>Grandchildren</td>
<td>White</td>
<td>5.22</td>
<td>43.87</td>
<td>44.58</td>
<td>81.92</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>5.09</td>
<td>43.85</td>
<td>47.85</td>
<td>80.83</td>
</tr>
<tr>
<td>Aunts/Uncles</td>
<td>White</td>
<td>11.84</td>
<td>43.77</td>
<td>44.99</td>
<td>58.88</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>9.30</td>
<td>43.86</td>
<td>47.98</td>
<td>65.38</td>
</tr>
<tr>
<td>Nieces/Nephews</td>
<td>White</td>
<td>7.44</td>
<td>43.87</td>
<td>44.94</td>
<td>74.06</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>7.63</td>
<td>43.91</td>
<td>47.86</td>
<td>71.07</td>
</tr>
<tr>
<td>1st Cousins</td>
<td>White</td>
<td>5.37</td>
<td>65.82</td>
<td>49.78</td>
<td>66.08</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>4.87</td>
<td>65.84</td>
<td>53.28</td>
<td>66.13</td>
</tr>
<tr>
<td>Non-Biological Kin</td>
<td>White</td>
<td>1.67</td>
<td>87.74</td>
<td>54.26</td>
<td>67.02</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>1.40</td>
<td>87.73</td>
<td>58.54</td>
<td>68.63</td>
</tr>
</tbody>
</table>

NOTE: The ‘Donor’ column is the percentage of kin of that relationship type simulated to be a suitable living donor – i.e., at least two HLA matches, a compatible ABO blood type, no contraindication health conditions, and no positive crossmatch. The remaining columns are the percentage of kin of that type excluded for the indicated reason. These categories are non-exclusive – if a family member was excluded for multiple reasons they are included in the numerator for all such reasons. No parents or children were excluded for HLA reasons because all parents and children share at least three HLA genes in common.
Table 4.7: Estimated Percentage Race Gap Explained, by Simulation Counterfactual

<table>
<thead>
<tr>
<th>ANY DONOR</th>
<th>Whites</th>
<th></th>
<th>Blacks</th>
<th></th>
<th>% Race Gap Explained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counterfactual</td>
<td>Mean</td>
<td>90% Interval</td>
<td>Mean</td>
<td>90% Interval</td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>0.58</td>
<td>(0.57,0.59)</td>
<td>0.63</td>
<td>(0.61,0.64)</td>
<td></td>
</tr>
<tr>
<td>Genetic</td>
<td>0.59</td>
<td>(0.58,0.60)</td>
<td>0.64</td>
<td>(0.63,0.65)</td>
<td>-14.48</td>
</tr>
<tr>
<td>Kinship</td>
<td>0.60</td>
<td>(0.59,0.61)</td>
<td>0.59</td>
<td>(0.58,0.60)</td>
<td>123.26</td>
</tr>
<tr>
<td>Health</td>
<td>0.58</td>
<td>(0.57,0.59)</td>
<td>0.62</td>
<td>(0.61,0.64)</td>
<td>-0.81</td>
</tr>
<tr>
<td>PRA</td>
<td>0.58</td>
<td>(0.57,0.59)</td>
<td>0.63</td>
<td>(0.62,0.64)</td>
<td>-18.72</td>
</tr>
<tr>
<td>All</td>
<td>0.61</td>
<td>(0.60,0.61)</td>
<td>0.61</td>
<td>(0.60,0.61)</td>
<td>95.84</td>
</tr>
</tbody>
</table>

| NUMBER OF DONORS | Whites         |          | Blacks         |          | % Race Gap Explained |
| Counterfactual | Mean  | 90% Interval | Mean  | 90% Interval |          |
| Baseline  | 1.10     | (1.08,1.11)  | 1.25     | (1.20,1.29)  | --       |
| Genetic   | 1.07     | (1.06,1.09)  | 1.29     | (1.25,1.33)  | -40.59   |
| Kinship   | 1.18     | (1.16,1.20)  | 1.10     | (1.07,1.13)  | 150.76   |
| Health    | 1.09     | (1.07,1.11)  | 1.25     | (1.21,1.29)  | -1.53    |
| PRA       | 1.08     | (1.06,1.11)  | 1.27     | (1.24,1.30)  | -20.39   |
| All       | 1.15     | (1.12,1.17)  | 1.15     | (1.13,1.17)  | 97.23    |

NOTE: 90% interval columns indicate the range in the indicated figure for the 5th and 95th percentiles of simulations for the indicated counterfactual condition. The ‘% Race Gap Explained’ column is the percentage degree to which the race gap between blacks (higher) and whites (lower) is ameliorated in the counterfactual condition. Negative values in this column indicate an increase in this gap; values between 0 and 100 indicate a partial amelioration, and values greater than 100 indicate a reversal of the inequality.
Table 4.8: Ratio of Living Donor Transplants to Simulated Available Living Donors, by Race

<table>
<thead>
<tr>
<th>Race</th>
<th>Living Donor Transplant (Observed)</th>
<th>Available Living Donor (Simulated)</th>
<th>% Available Transplanted</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>0.192</td>
<td>0.585</td>
<td>32.8</td>
</tr>
<tr>
<td>Black</td>
<td>0.088</td>
<td>0.618</td>
<td>14.2</td>
</tr>
</tbody>
</table>

NOTE: ‘% Available Transplanted’ is calculated as (Transplant / Available)*100, and interpretable as the estimated percentage of suitable living donors who actually donate a kidney for transplantation. Observed living donor transplant rates by race are subsetted to candidates on the waiting list 2000-2007 only to adjust for censoring differences by race.
Figure 4.1: Theoretical Framework
Figure 4.2: Illustration of Research Design

NOTE: The black circle indicates the reference transplant candidate; other circles represent kin. The blue sections of each kin circle represent the probability that a person of that relationship type will be a medically and genetically suitable living donor for the reference person. The black X indicates that this person is deceased. This figure is for illustrative purposes only.
NOTE: This figure is for illustrative purposes only. The spreadsheet on the left represents the kidney transplant waiting list data. The ‘u’ column in this spreadsheet represents values drawn from a uniform random distribution. The spreadsheet on the right represents persons in the PSID data, from which kinship ego networks will be probabilistically assigned to waiting list candidates. The rows highlighted in dark indicate the PSID observations whose kinship networks were simulated to be assigned to waiting list candidates, and the arrows link the merged observations. Observations are merged based on identical race, education, age, and gender combinations, then PSID observations meeting these requirements are assigned proportionate to their sample weights, using the uniform random draw assigned to the kidney transplant candidates (‘u’) compared to the weight range assigned to the PSID candidate (‘Range’ column). The range column is constructed to have a range equal to the proportion of total weights for demographically identical persons represented by the observation’s weight. Further details are provided in the text of the paper.
Chapter Five: Conclusion

Despite the attention which has been lavished on the topic of social inequalities in health in recent years, relatively little research has investigated disparities in kidney disease and transplantation outside of medical and public health circles (but see Fox and Swazey 1978; Fox and Swazey 1992; Healy 2006; Lock 2002; Sharp 2006; Shoham et al. 2008). In this dissertation, I have argued that a sociological perspective on the allocation of kidneys for transplantation improves our understanding of this important topic. Furthermore, I argue that the case of social inequalities in kidney transplant could improve sociological understanding of allocative systems as well.

The Value of a Sociological Perspective on Kidney Transplantation

A sociological approach to social inequalities in the kidney transplantation system offers a number of insights. First, a sociological perspective emphasizes that kidney transplantation is a social system with a set of rules governing kidney allocation. The facets of this allocation system evolve over time in response to increasing knowledge of immunology and surgical techniques, as well as changing political pressures and the system’s self-understanding. The primary function of UNOS from a stratification perspective is to establish “the rules of the game” (Schwalbe 2007) by which transplant candidates seek and obtain kidney transplants. These rules are primarily established through the practices governing waitlisting, deceased donor allocation, and potential living donor evaluation. Changing the rules over time, as UNOS does periodically,
evolves the structure of this social system, determining in part which biosocial differences between subpopulations will serve as the mechanisms of social inequality.

Second, a sociological perspective highlights the permeability and limitations of this system. Although UNOS has great power to shape the fates of transplant candidates and recipients, and although it uses this power in large part to promote social equity in the transplantation system, it has little power to influence the social structure outside of its institutional confines. Distributional differences in immunological genes, places of residence, kinship patterns and access to salubrious socioeconomic resources are outside of its purview. This dynamic highlights the difficulties of constructing a just allocation system in a deeply stratified society. So many facets of social life in the U.S. are subject to social inequalities that even objectively justifiable allocative rules will tend to result in relatively poor outcomes for traditionally disadvantaged groups.

Third, the findings of this research highlight the limitations of taking a primarily medically-based, individualistic approach to understanding social disparities in transplantation outcomes. A great deal of medical research on social disparities in the transplantation system emphasizes the role of group differences in genetic, immunological, and attitudinal factors (e.g., Navaneethan and Singh 2006; Ting and Edwards 2004). While the findings of the present research agree that at least the first two factors play a key role, a sociological perspective emphasizes that many other factors are important, particularly in waitlisting behavior and pursuit of a living donor kidney transplant. In the first case, it is likely that local waiting list dynamics, geography, and socioeconomic resources are important determinants of one’s ability to enroll in multiple waiting lists and enroll in the waiting list preemptively, which other research has shown

37 This literature is certainly not limited to these factors, but they do predominate.
to be an important mediator of socioeconomic disparities in transplantation outcomes (Ardekani and Orlowski 2010; Axelrod et al. 2010; Kasiske et al. 1998; Keith et al. 2008; Merion et al. 2004). In the second case, the confluence of kinship structure and characteristics with the network of family relationships and attitudes will likely explain much concerning racial disparities in LDKT. To their credit, many medical researchers have recently begun to think about the problem in this way, as well (Arthur 2002; Clark et al. 2008; Fathi-Ashtiani et al. 2007), although much of their conceptualization of social network effects is limited to factors such as information diffusion, marital quality, and social support. A notable exception to this tendency is provided by a recent paper (Ladin and Hanto 2010), which argues for a fuller conceptualization of social network effects, and anticipate my research on the living donor kidney transplant opportunity structure 38.

Taking a sociological perspective when investigating social disparities in transplantation also has methodological implications. For one, it emphasizes that individual outcomes are not individualistic – rather, who gets a transplant and when is fundamentally dependent on candidates’ own history as well as the characteristics and outcomes of other transplant candidates and deceased donors. The typical regression-based methodologies applied to the study of inequalities in kidney transplantation are ill-equipped to account for this important facet of this system and likely result in substantial coefficient biases. In addition to these methods’ technical shortcomings for this topic, such research misses a key opportunity to directly model the rules of the game. Because

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38 They write, “From an ethical perspective, if we find that Black patients exhibit low rates of LDKT due to the ineligibility of their social network (e.g. high prevalence of hypertension, diabetes, or obesity in social network), this presents a significant disparity between chances of Whites, who can rely on social contacts, and Blacks whose only option may be wait listed. Identifying which social networks contain eligible donors and how those networks might be approached and strengthened is critical to increasing successful LDKT” (Ladin & Hanto 2010:476).
the allocation algorithm for kidneys is publicly available, by modeling this process directly we are able to achieve far better understanding of the mechanisms by which inequalities are produced and potentially ameliorated.

Finally, sociological research on the family suggests potential mechanisms by which African Americans could obtain living donor kidney transplants at lower rates than whites despite their apparently similar access to suitable living donors in their kinship networks. Kidneys for transplant are gifts, and gifts are subject to rules of structured exchange (Nelson 2000; Stack 1974). Norms of reciprocity are a frequent element of this exchange structure and much research suggests that these reciprocity demands are disproportionately strong for African Americans (Miller-Cribbs and Farber 2008; Testa and Slack 2002). Previous work has termed the strains such a debtor-creditor relationship can place on kin relations the “tyranny of the gift” (Fox and Swazey 1978; Fox and Swazey 1992) because kidney transplants are so significant and irreversible. Faced with the prospect of such strains, it may be that many African Americans forgo seeking an LDKT rather than potentially cause irreparable harm to their kin relations.

**Lessons from the Case of Kidney Transplantation for Sociology**

Sociologists in the social stratification tradition frequently use the analogy that societies are an allocative system which creates valued goods and social positions and sorts individuals according to a particular logic (e.g., Davis and Moore 1945). (Of course, which logic is thought to govern this process varies widely.) Because we have access to such high quality data on kidney transplantation and the rules of allocation in this system, the findings of the present research offer a number of lessons for those who may seek to
understand the properties of allocation systems generally and health inequality specifically.

First, the nature of the kidney allocation system orients one to key features of more sociologically familiar allocation systems. In the kidney transplantation system, over time a series of valued resources (deceased donor kidneys) become available, and a set of persons seeking this resource (transplant candidates) compete to obtain these resources. Some of these resources are more valued than others (since some kidneys are healthier than others) and the value of the resource to the persons seeking it varies by the seeker-resource match (due to differences in immunological compatibility which are partially dyadic between the donor and potential recipient). Finally, a set of decision makers determine to whom this resource should be offered based on a set of criteria which they feel serve their institution’s interests (the deceased donor kidney allocation system), and those who are offered this resource may accept or refuse this offer based on their own reasoning (when transplant candidates decide whether to accept a DDKT).

I have argued that the situation just described requires that one abandon standard regression-based analyses and individualistic thinking because such a system means that individual outcomes are inherently interdependent. The exact same point could be made about the labor market or the competition for college admissions. Looking at the above paragraph, substitute the following phrases into the parentheses in order: “jobs,” “job seekers,” “because some jobs offer better amenities and working conditions than others,” “because job seekers vary in their occupational preferences,” “the hiring decision making process,” and “when job seekers decide whether to accept a job offer.” This description is
equally applicable to the labor market and kidney transplantation. A similar exercise could describe college admissions, as well.

This last point was not merely intended to be clever. The methodological and theoretical implications of adopting the interdependency perspective in the socioeconomic attainment process are the same as in the kidney transplantation system. Of course, the obstacles to collecting the data necessary to conduct a study parallel to the present ones are far more daunting in the case of the labor market than in the kidney transplantation system. The size of the system is far larger, for one, and the allocative rules are likely occupation-, industry-, and firm-specific. We probably cannot ever hope to have access to the type of data I have employed in this dissertation for the labor market system as a whole. But it is essential that future researchers in socioeconomic stratification keep in mind that, at minimum, standard regression approaches to this topic are glossing over crucial elements of this key sociological process.

Second, the relatively obvious efficiency-equity tradeoff observed in the kidney transplantation system calls attention to the likelihood of similar potential tradeoffs in more common topics of sociological inquiry. In kidney transplantation, among many other things, the age of the candidate and degree of histocompatibility between the donor and the recipient are significant predictors of post-transplantation outcomes (Danovitch and Cecka 2003; Jassal et al. 2005). Because the availability of organs is limited and DDKs are not construed to belong to anyone living, UNOS takes seriously its perceived responsibility to allocate these life-saving resources in a manner which maximizes the population benefit thereof. However, an allocation policy strictly focused on maximizing efficiency would be far more inequitable – a far larger proportion of kidneys would then

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39 And I thank Ted Mouw for pointing out the parallels between these two systems to me.
be allocated to the young (because they typically gain health benefits above those garnered by older persons) and, somewhat less so, the white (because they on average have more similar ABO and HLA profiles to the donor pool than do racial and ethnic minorities).

This tension, familiar to economists (e.g., Blank 2002; Okun 1975), is rarely discussed by sociologists. Of course, measuring any potential tradeoffs between efficiency and equity in the labor market or in college admissions would be quite tricky because the factors which will maximize efficiency for these institutions’ gatekeepers are less well understood and the measurement of efficiency is less well-defined. The social stratification literature has often treated group differences in outcomes as a prima facie wrong. Although certainly all can agree that such situations are lamentable, careful thought should be spent considering the potential costs of equality-at-all-costs thinking. For instance, a sure way in which to produce total equality in the kidney transplantation system would be to adopt a “first come, first serve” allocation model (where “first come” would be defined as the time of onset of ESRD or CKD to account for differential waitlisting behavior). However, such a policy would at this time be sure to greatly reduce the efficiency of the kidney transplantation system and would certainly harm many of its supposed beneficiaries when their transplanted kidneys were rejected at higher rates than is currently observed. Furthermore, because prior transplants are associated with substantially higher PRA values, such a policy would reduce their prospects for obtaining a well-functioning transplant in the future.

Although the human costs of eliminating any potential source of group disparities in the labor market and education are likely to be less severe, they are likely to be
nonetheless very real. If employees are not well matched to their positions, then other employees at a firm and the firm’s customers suffer. If persons attend college who are not prepared to benefit from it while other students who could are turned away, the educational benefits of the university system is diminished. Certainly many inequities in the labor market and educational systems are observable, and many are the results of real injustices. However, in other cases observed inequalities in outcomes are attributable to perfectly valid criteria designed to promote efficiency in the system in question. Unfortunately, as I have argued previously, in a racially and socioeconomically stratified society many efficiency-promoting criteria, such as prior grades and standardized test scores, are likely to be racially and socioeconomically stratified as well, and the causes of these disparities should be closely investigated. However, observed inequalities in access to a system do not necessarily reflect injustices in that system.

Third, social disparities in the kidney transplantation system emphasize the limits of disparities in financial resources and “access to care” in the explanation of health inequality. Certainly, not all potential costs are covered – in particular, immunosuppressant costs after the first three years post-transplantation likely plays a key role (Gordon et al. 2008). However, to an unusual degree for the U.S. socioeconomic disparities are leveled in the kidney transplantation system due to the availability of universal health insurance coverage through the Medicare ESRD program. Although social groups differ sharply in the probability of successfully enrolling in the waiting list (Epstein et al. 2000), once on the waiting list all persons have affordable access to transplantation, yet large differences remain in the probability that members of different groups will obtain a transplant. This finding is buttressed by quasi-experimental research
that document limited health-promoting effects of expanded insurance access (Finkelstein et al. 2011; Newhouse and Group 1993). Although socioeconomic resources and health insurance do play a substantial role in population health, ameliorating these inequalities within the health system may not be a panacea for health disparities.

Fourth, increasingly social scientists are incorporating information on biomarkers and genetic data into their study designs, which is a welcome development. In the latter case the usual approach is to select a set of genes and a set of outcomes and attempt to determine the association of the genes with the outcome, often stratified by environmental measures in the gene-environment interaction tradition (e.g., Caspi et al. 2002). However, the present research emphasizes that processes inside the body and in interaction with the immediate environment are not the only mechanism by which genes can influence health outcomes. In the case of kidney transplantation, the consequences of one’s ABO or HLA genotype are not of this usual breed. Instead, the effect thereof depends on the distribution of genotypes in the deceased donor pool, the transplant candidate pool, and one’s kinship and social networks.

In this way the effects of genetics in the kidney transplant system embody the idea of the “meta-genomic environment” (Conley et al. 2011). When one is considering gene-meta-genomic environment interactions, it is the intersection between one’s own genes and others’ which is of crucial importance. In the case of the present research, ABO and HLA types are not fundamentally important in themselves – there is no evidence that these genes directly influence one’s mortality hazards, for example. However, the presence of racial differences in the distribution of these genotypes, combined with the facts that in the U.S. certain racial and ethnic groups are numerical minorities and that
histocompatibility in the antigens coded by these genes is predictive of post-transplant outcomes, means that group differences in these genes’ distributions are key mediators of racial and ethnic inequality in this system. Although the application of the concept of the meta-genomic environment is perhaps not so obvious or likely in other cases, its applicability should be investigated in future research.

Finally, this research highlights the value of studying specific causes of ill health alongside the more traditional sociological and demographic practice of studying broad differences in health outcomes. Through the latter avenue much has been learned about the nature and causes of social inequalities in all-cause mortality, major causes of death, and highly prevalent causes of morbidity such as cardiovascular disease, obesity, and diabetes. However, while it is my hope that such research will continue apace, the ability of the present work to capture the major mechanisms of social inequalities in the kidney transplantation system highlights the inability of much research adopting a broader perspective on health to do so.

Many researchers in the area of social inequalities in health agree that a key challenge facing this literature is to measure and identify the mechanisms linking social position to health outcomes (e.g., Adler and Rehkopf 2008). I completely agree. However, I find it unlikely that a broad health research program alone is capable of achieving this goal. First, social disparities in patterns of ill health vary widely by disease (Smith 2003), as seen in my work on the living donor kidney transplant opportunity structure. While it is likely that the effect of key mechanisms of ill health vary by morbidity type and mortality cause, it is equally likely that many of the key mechanisms themselves vary widely between different causes of ill health. By studying more specific
causes of ill health in great detail while still keeping an eye on the broader picture of population health inequality, I propose that the mechanisms linking social position to health outcomes, and the diversity of these mechanisms, will be far better understood. It is my hope that my dissertation has contributed to this desirable outcome.

**Policy Implications for Transplantation**

The results of the analyses in this dissertation also suggest a number of potential sites of intervention should policymakers wish to take additional steps to ameliorate social inequalities in the kidney transplant system. The two most significant steps which could be taken would be to reconsider the role of geography in the kidney allocation system and to make additional efforts to promote living donor kidney transplants as an option for racial minority and lower SES transplant candidates. These are the major mediators of overall social inequalities in the KT system and the most amenable to direct and immediate intervention measures.

Basic research efforts into post-transplant care, and especially immunosuppression drugs, could also promote racial and SES equality in the KT system. The previously more substantial role of HLA genes in the kidney allocation system has been reduced over time as improving immunosuppressant regimes have permitted their reduction without unacceptable losses in the efficiency of the system. It could be that future improvements in the success of these efforts could continue to promote racial equality in transplantation.

Currently UNOS is considering changes to kidney allocation policies which are intended to jointly improve the efficiency and equity of the KT system\textsuperscript{40}. They propose to

\textsuperscript{40} A full discussion of the specifics of this new proposed system is beyond the scope of this work, but the details are available at
do so by having donor-candidate age match play a vastly increased role in this system and to combine this age sorting mechanism with components accounting for the estimated quality of the donor kidney and the candidate’s expected survival time post-transplantation. Although it may well be, as UNOS argues, that such a system would reduce racial and socioeconomic inequalities in kidney transplantation, because organ donors are disproportionately young this system would also reduce the share of kidney transplants awarded to older members of the KT waiting list. It may be, then, that candidate age will become an increasing determinant of transplantation prospects in the future.

**Needed Research**

A number of questions on the topic of inequalities in the kidney transplantation system merit future research, which I hope to explore in future research. First, the largest racial and socioeconomic differences in outcomes are attributable to differential rates of LDKTs, yet relatively little is known about the processes by which families and friends navigate the question of who, if anyone, should be evaluated for donation, and how these processes intersect with events within transplant centers. Deep description based on careful ethnographic observation of these processes in families in different social positions would be a welcome contribution to the literature. It is my hope that I can gain access to members of the waiting list in the future to conduct such research. Furthermore, my findings on the likely racial differences in the LDKT opportunity structure had to rely on secondary data on kinship, health, and genetic distributional patterns in the U.S. It is

my hope that, in the longer term, direct data on the characteristics of donor families may be collected to verify the conclusions of this research.

Turning to the DDKT allocation system, a number of topics merit future attention. First, geographic inequalities in kidney transplant outcomes are large (Mathur et al. 2010) and although the medical literature increasingly recognizes this issue, much remains to be learned. As with much else in the social science literature on transplantation, Healy’s (2006) work points the way, investigating the role of population and organizational characteristics in the collection of DDKs for transplantation and suggesting key characteristics of the transplant exchange network. I have gained access to data on the hospital, OPO, and regional affiliations of most kidney transplant candidate and donors in the U.S., so the recent availability of this data permits me to further his analyses in future work. Transplant centers are nested within a complex exchange network structured by the allocation algorithm, in which kidney sharing is structured by the availability of any perfect HLA match candidates, geography, and a system of kidney debts and paybacks between OPOs. My future research will investigate the properties of this system and whether transplant centers’ position in the kidney exchange network mediates social and geographic inequalities in transplantation outcomes.

**Conclusion**

Although transplantation, with notable exceptions, is not a traditional topic of sociological research, the study of societies and of transplantation have much to offer each other. Adopting a sociological perspective which situates transplant candidates as participants in an allocative system with clearly defined distributive rules and recognizes the permeation of familial, geographic, metagenomic, and immunological contexts into
this system, this research produces a number of key findings. First, substantial racial inequalities in kidney transplantation outcomes are primarily the result of racial differences in living donor kidney transplants, geographic residency, and the distribution of immunologically important genes. Second, educational attainment is linked to transplant outcomes primarily through the type of transplants obtained. Furthermore, higher educated candidates are advantaged by their higher rates of living donor kidney transplantation and higher probability of genetic compatibility with the deceased donor pool, whereas lower educated persons are advantaged by their places of residence and the dynamics of immunological crossmatching. Finally, black-white disparities in living donor kidney transplantation do not appear to be the result of group differences in the availability of suitable donors in their kinship networks. However, the findings of this research do suggest that each white kin is more probable than black kin to be a suitable living donor. Given the relatively sparse number of potential donors most transplant candidates have evaluated for donation, it is likely that this higher probability of suitability is a major determinant of racial differences in living donor kidney transplantation rates. Taken together, these findings significantly improve on previous research in the medical literature on the determinants of social disparities in kidney transplantation outcomes.
References


