Does Whom Patients Sit Next to During Hemodialysis Affect Whether They Request a Living Donation?

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Key Points

- Hemodialysis patients formed relationships with the other patients in the clinic whom they sat next to and had similar transplant behaviors.
- Participants who requested a living donation formed more relationships within the clinic, and discussed transplantation with each other.
- Our study identifies health-behavior homophily that can be used for future hemodialysis clinic social network behavioral interventions.

Abstract

**Background:** The seating arrangement of in-center hemodialysis is conducive to patients forming a relationship and a social network. We examined how in-center hemodialysis clinic seating affected patients forming relationships, whether patients formed relationships with others who have similar transplant behaviors (*homophily*), and whether these relationships influenced patients (*social contagion*) to request a living donation from family and friends outside of the clinic.

**Methods:** In this 30-month prospective cohort study, we observed the relationships of 46 hemodialysis patients in a hemodialysis clinic. Repeated participant surveys assessed in-center transplant discussions and living donor requests. A separable temporal exponential random graph model estimated how seating, demographics, in-center transplant discussions, and living donor requests affected relationship formation via *sociality* and *homophily*. We examined whether donation requests spread via social contagion using a susceptibility-infected model.

**Results:** For every seat apart, the odds of participants forming a relationship decreased (*OR* 0.74, 95% confidence interval CI [0.61, 0.90], *p* = 0.002). Those who requested a living donation tended to form relationships more than those who did not (*sociality, OR* 1.6, CI 95% [1.02, 2.6]; *p* = 0.04). Participants who discussed transplantation in-center were more likely to form a relationship with another participant who discussed transplantation than with someone who did
not discuss transplantation (homophily, \textit{OR} 1.9, CI 95\% [1.03, 3.5]; \textit{p} = 0.04). Five of the 36 susceptible participants made a request after forming a relationship with another patient.

**Conclusions:** Participants formed relationships with those whom they sat next to and had similar transplant behaviors. The observed increase in in-center transplant discussions and living donation requests by the hemodialysis clinic social network members was not because of social contagion. Instead, participants who requested a living donation were more social, formed more relationships within the clinic, and discussed transplantation with each other as a function of health-behavior homophily.
Introduction

In-center hemodialysis clinics are conducive to the formation of patient social networks because patients are treated in a group setting. Patients are seated together for several hours thrice weekly (1-4) and when people are near each other repeatedly, they often form relationships (5, 6). The set of these relationships (links) is called a social network (7) (see Table 1). Understanding the factors that lead patients to form a social network within the hemodialysis clinic is a research priority because patients’ social networks have been shown to both improve and worsen chronic diseases (5, 6, 8-15). Furthermore, social network interventions improve outcomes in these chronic diseases (8, 9, 14, 15).

In a prospective cohort study of a hemodialysis patient social network (1), we showed that patients formed a hemodialysis clinic social network in which they discussed health, kidney transplantation, and completed more of their transplant testing if their network members also completed their testing. We could not differentiate, however, whether this similarity in transplant behavior was via social contagion (13, 14, 16) (Table 1), in which participants motivated each other to complete transplant testing, or rather, participants, who were motivated to complete their testing, formed relationships with similarly motivated participants via health-behavior homophily (8, 17, 18) (Table 1). This is because the completion of steps towards transplantation is not suitable for a contagion model because it is multistep process (19) that requires multiple acts and can take many months or years to complete. Social contagion models are better suited for single behaviors that occur at a single point in time such as asking a family member or friend to consider being a living donor, which we will refer to as requesting a living donation.

In our previous research of this cohort (1), a greater proportion of hemodialysis clinic social network members discussed kidney transplantation with other participants and requested a
living donation compared to participants who were not members of the hemodialysis clinic network (isolates). This association between network participation and living donor requests is notable because many people are uncomfortable requesting a donation (20, 21) and difficulties requesting a living donation are a significant barrier to living donor kidney transplantation. We hypothesize that if participants formed a relationship and discussed transplantation with someone in the hemodialysis clinic who made a living donor request, the participants could be influenced via social contagion to request a living donation.

In this study, we first examined how seating distance and demographic characteristics were associated with patients forming a relationship. We then examined the social network theories of sociality (some people are more social than others, Table 1) (17), health-behavior homophily, and social contagion that could explain the increase in network participants who discussed living donation with other patients and requested a living donation from family and friends. Understanding the formation and function of the hemodialysis clinic social network should inform future interventions that could increase the rate of living donor kidney transplantation.

**Methods**

*Study Design, Setting, and Participants*

Between August 2012 and February 2015, we conducted a prospective observational cohort study (1) of the formation and role of social networks in a newly opened, twelve-station hemodialysis clinic in Philadelphia. Patients were eligible to participate if they had end stage kidney disease (ESKD), spoke English or Spanish, and were 18 years old or older. The Temple University Institutional Review Board approved the study protocol; written informed consent was obtained from all participants. The clinical and research activities reported here are
consistent with the Principles of the Declaration of Istanbul as outlined in the “Declaration of Istanbul on Organ Trafficking and Transplant Tourism” and also adheres to the Declaration of Helsinki (22, 23).

Variables

The exposure variable was a participant’s exposure to other participants in the hemodialysis clinic. We had two outcome variables: (1) whether a relationship (link) was formed and (2) whether a participant requested a living donation after joining the study. Predictors of relationship formation and requesting a living donation included shift assignment, seating distance, demographic variables (age, sex, race, and ethnicity), and health behaviors (in-center kidney transplant discussions with other patients, requesting a living donation before link formation). Potential confounders of relationship formation were language used (Spanish speaking only), dialysis vintage, and time within the study. Eligibility for transplant was a potential confounder for requesting a living donation.

Data Collection

The Dialysis Patient Transplant Questionnaire (DPTQ) (24) was used for data collection (see supplement). The DPTQ collects demographic information such as race and ethnicity (for which participants can select more than one option), marital status, as well as transplant preferences and attitudes (24). The DPTQ asks participants whether they had discussed a kidney transplant with anyone and, if so, with whom. Another item asks participants whether they had requested a living donation (yes, no, or not sure). Questionnaires were administered within three months of admission to the clinic and they were repeated every three months. Demographic and medical data, such as age, sex, medical cause of ESKD, and eligibility for transplantation, were extracted from the patients’ medical records.
Network Identification and Conversation Measurements

We directly observed the participants’ interactions to correct for any potential recall or social desirability bias (25) in patient self-reported social interactions. The trained research staff observed and documented patient interactions for two hours per day on a weekly or biweekly basis from the centrally located nurses’ station within the treatment area, as well as in the waiting area and outside the clinic while participants waited for transportation. All patient interactions in the form of verbal communication, from a simple greeting to a long conversation, were logged as indicating a relationship (link). The content of these conversation such as whether transplantation was discussed was obtained from the DPTQ.

This 30-month study was divided into ten three-month periods (see Figure 1). Observations within each three-month period were compiled into a sociomatrix (a matrix of relationships) that coincided with the questionnaire data that was collected every three months. This resulted in eleven sociomatrices, including the starting point at time zero, which had no links. We assumed that once a link had been formed, knowledge was transferred, and that the link would not be dissolved unless the participant left the clinic (Figure 2).

Shift, Seating, and Distance

The clinic’s charge nurse was blind to the network portion of this study and assigned participants to their seats, and shifts, which were either a morning or afternoon shift on Monday, Wednesday, Friday (MWF), or Tuesday, Thursday, Saturday (TTS), based on clinical judgment, including Hepatitis B serological status and hemodialysis prescription. Participants could request a shift assignment, but they did not choose their seat. A participant’s shift and seating assignment and subsequent changes were recorded as part of clinic policy. Because participants changed seats and shifts over the course of the study, participants were classified as MWF or TTS based
on the shift that they spent the most time on. This dialysis clinic’s twelve-seat treatment area measured 44 feet (13.4 meters) by 35 feet (10.7 meters; Figure 3). To account for patients not always being assigned to the same seat, we calculated the mean seating distance in terms of face-to-face geodesic (shortest) distance between their two seats. We took the sum of the distances between the participants and divided it by the number of times each pair of participants were on the same shift. The maximum distance between participants on the same shift was 5.83 seats, and for patients who never sat next to each other, the distance was defined as 7 seats.

Statistical Analyses

Descriptive Statistics

We examined the questionnaire and network variables that were associated with discussing transplantation with other participants and with requesting a living donation (Table 3, Supplemental Table 1). Chi square and Fisher’s exact tests were used for the categorical variables, and ANOVA was used for continuous variables.

Modeling Link Formation

We used a separable temporal exponential random graph model (STERGM) (26) to analyze the network as a multivariate observation in which the formation of links in the network depended on the participants’ attributes as well as the structural processes of the networks (see Table 1). We used geometrically weighted degree (GWDegree) to model centralization and geometrically weighted edgewise shared partner (GWESP) to model clustering in the STERGM (27). GWDegree and GWESP have decay parameters that range between 0 and 1, and they were optimized to the lowest Akaike information criterion (AIC) for the most parsimonious model (27). We then added hemodialysis clinic attributes to the model such as shift and mean seating distance between patients. Next, we examined the demographic attributes (age, sex, race,
ethnicity, religion, education, dialysis vintage, and eligibility for transplant) that predicted sociality and homophily. Models were then constructed to test health-behavior homophily using in-center transplantation discussions and living donation requests. For each model, the observed network was compared with 100,000 randomly generated Markov random graphs (networks) using maximum pseudo-likelihood estimation and Monte Carlo maximum likelihood estimates (MC MLE) (26).

**Social Contagion model**

Our social contagion model was a susceptible-infected (SI) contagion model (3) (see Figure 1). Participants who had not yet requested a living donation were considered “susceptible.” If participants reported requesting a living donation either before or during the study, they were considered “infected.” Once “infected,” the participants remained “infected” and could not “recover” or become “reinfected.” Figure 1 describes our contagion model in which a participant becomes “infected” after being exposed to another “infected” participant (14).

**Sensitivity Analyses**

We examined the STERGM diagnostics and assessed their goodness of fit by comparing simulated data to the actual data (28). To examine the robustness of the model to survey error, we performed random data manipulations. We randomly changed participants who had transplant discussions to not having discussions and vice versa for five participants (10% of the data) and then for 10 participants (20% of the data), and then we re-estimated the model using these datasets. Each of these data manipulation procedures was performed five times.

**Software**
Software used included SPSS version 25 (29) for descriptive analyses and the following R packages: Statnet (28), STERGM (26), and NDTV (30) for STERGM model analysis and visualization. All tests were two tailed, with a $p < 0.05$ to be considered statistically significant.

**Missing Data**

All questionnaires were complete because the research staff assisted participants with any incomplete questions after self-administration.

**Results**

**Study Participation**

Of the 49 patients who were eligible to participate, 46 patients participated and completed the baseline survey and forty patients (89%) completed at least one follow-up survey. Surveys were administered in English (78%) and Spanish (22%), (see Table 2). Participants reported their race and ethnicity as White Hispanic (37%), Black (33%), Non-Hispanic White (22%), and Multiethnic (9%). Forty-four percent of Hispanic participants took their survey in English although being fluent in Spanish. Eight participants (17%) were on the kidney transplant waitlist before joining the study. By the end of the study, 17 participants (37%) were on the waitlist. No participants received a living donor kidney transplant over the course of the study. The majority (91%) of participants were treated by the same nephrologist.

**Demographic and Clinical Variables Associated with Living Donation Requests**

Table 3 shows the variables associated with participants making a living donor request to a loved one, family member, or friend. Eleven participants requested a living donation before admission to the clinic and enrollment in the study. Among the 36 participants who did not request a living donation before joining the study and were considered “susceptible,” 13 requested a living donation after joining the study. All the participants who made a request
before joining the study or after joining the study wanted a living donor kidney transplant. Among those who did not request a living donation, 68% wanted a living donation. A greater proportion of participants who requested a living donation were on the transplant waitlist or received a deceased donor kidney transplant by the end of the study than participants not on the waitlist (55% who requested before vs. 54% who requested after vs. 18% who never requested were on the waitlist, $p = 0.04$, Table 3). None of the other demographic or clinical variables were associated with requesting a living donation (Supplemental Table 1).

Network Participation, Patient to Patient In-Center Transplant Discussions, and Living Donation Requests

Of the 11 participants who requested a living donation before admission to the clinic, 10 participated in the social network (91%), and 8 had in-center transplant discussions (73%). Of the 13 participants who requested a living donation after joining the study, 11 participated in the network (85%), and 5 had in-center transplant discussions (39%). Among the 22 participants who never requested a living donation, 11 participated in the social network (50%), and 2 had in-center transplant discussions (9%). These associations between participating in the network and making a living donor request and between having in-center transplant discussions and requesting a living donation were significant ($p = 0.02$ and $p = 0.001$, respectively; see Table 2).

Other People that the Participants Discussed Transplant with

A greater percentage of participants who requested a living donation before joining the study (73%) and after joining the study (62%) discussed transplantation with the hemodialysis clinic staff compared to those who did not request a living donation (24%, $p = 0.01$, Table 2). Those who requested a living donation before (61%) and after joining the study (26%) also
discussed transplantation more with friends outside of the clinic than those who did not request a living donation (55%, \( p = 0.047 \)).

**Shift Assignment and Seating**

Most participants (70%) were assigned to an MWF shift (Table 2). Because seat assignment changed for many participants, we calculated the mean seating distance between the participants, which was 4.6 seats (SD 1.9), with 29% of the participants never sitting side by side. Eleven percent of the interactions occurred in the waiting room between patients who were assigned to the same day but never sat together on the same shift.

**The Dynamic Network and Transplant Behaviors**

To understand whether the relationships in the network influenced requesting a living donation, we must first understand the dynamics of network formation. The study started with six participants and over the course of the 30-month study period, an additional 40 participants were admitted to the clinic. Fourteen participants left the clinic, with two who transferred out, seven who received a deceased donor transplant, and five who died. Figure 1 shows the formation of the social network over 3-month intervals represented by each panel (Time 0 not shown). By Month 30 (Time 10), there were 20 participants who formed a large network, shown in the center of the Time 10 panel, which consisted of 16 MWF participants (triangles) and 4 TTS participants (circles). The 13 who were isolates, are shown on the periphery of the panel. The layout in panel 10 does not represent seating distances; rather, the participants with more links are in the center of the panel (30).

Figure 1 also illustrates who had in-center transplant discussions and/or requested a transplant over the course of the study. At month 3, when there were only five participants on the MWF AM shift, the two large triangles represent two participants who had in-center transplant
discussions within the clinic and had already requested a living donation (black color), and the small black triangles represent two participants had requested a donation before starting the study but did not have in-center transplant discussions. One of the participants represented by a small black triangle was linked to a participant who had requested a living donation after joining the study (red triangle). This is an example of a participant who requested a living donor transplant influencing another participant to request a living donation. By month 30, among the 20 participants who formed the connected network, 9 had in-center transplant discussions, and 11 had not discussed transplantation in-center. Eleven members of this connected network had requested a living donation, with 7 requesting before the study and 4 after enrolling in the study. Figure 2 shows the increase over time in the number of participants in the clinic as well as the number of participants who had in-center transplant discussions and requested a living donation. The number of participants who had in-center transplant discussions and those who requested a living donation both increased until Time 8, when three participants who had requested a donation left the clinic (two received a deceased donor transplant and one died).

**Modeling Network Formation, Homophily, and Health-Behavior Homophily**

We examined the effects of seating distance, demographics, and transplant discussion behaviors on network formation. Table 4 shows the results of the STERGM and the log odds of participants forming a link. Model 1 (Full Model) includes the structure of the network, clinic shift and seating, and sociality and homophily, by age, sex, race, ethnicity, and transplant behaviors of in-center discussions and requesting a living donation as predictors of link formation. Model 2 focuses on sociality and homophily of in-center transplant discussions, and Model 3 reports the sociality and homophily of requesting a donation. The structural variables (see Table 4, Model 1) indicate that over time the participants formed a sparse network in which
not everyone was linked, relationships were clustered among groups, and a few network members had many relationships (centralization; see Time 10 in Figure 1). Participants on the TTS shift were more social (sociality), being 1.4 times more likely to form a link (OR 1.4, 95% CI [1.02, 2.06]; \( p = 0.04 \)) as compared to MWF participants. Overall, participants were 31 times more likely to form a link (OR 31, 95% CI [4.4, 213]; \( p < 0.001 \)) with a participant on the same day assignment than a participant on a different day. Interestingly, for every seat apart, the odds of participants forming a link decreased by an OR 0.74 (95% CI [0.61, 0.90], \( p = 0.002 \)).

We then examined homophily based on age, sex, race, and ethnicity, and we found that Hispanic participants had a lower odds of forming a link (OR 0.39, 95% CI [0.16, 0.97]; \( p = 0.04 \), Table 4, Model 1: Full Model) with another participant than did non-Hispanic White participants. Hispanic participants, however, were 10.1 times (OR 10.1, 95% CI [2.6, 40.0]; \( p < 0.001 \)) more likely to form a link with another Hispanic participant than with a non-Hispanic participant. Whether participants completed their survey in Spanish did not significantly predict link formation (Supplemental Table 2). Other participant variables that did not predict link formation via sociality or homophily were age, sex (Table 4), religion, dialysis vintage, education, and transplant eligibility (Supplemental Table 2).

We modeled health-behavior homophily by examining whether participants formed links based on similar transplant-related behaviors. Participants who discussed transplantation in-center were 1.9 times more likely to form a link with another participant who discussed transplantation in-center (OR 1.9, CI 95% [1.03, 3.5]; \( p = 0.04 \), Table 4, Model 2 Transplant Discussions) than a participant who did not have in-center transplant discussions. Conversely, participants who did not have in-center transplant discussions were 1.9 times more likely to form relationships with each other than with a participant who had in-center transplant discussions.
Participants who requested a living donation were more social (sociality) because they were 1.6 times more likely to form a link than participants who did not request a donation (OR 1.6 CI 95% [1.02, 2.6]; p = 0.04, Table 4, Model 3 Requesting a Donation).

Figure 3 demonstrates the probability that a 55-year-old participant (the mean age in the study) on the TTS shift who has in-center transplant discussions forms a link with another participant who has in-center transplant discussions and sits adjacent to them is 13.8%. This probability decreases to 10.8% if they are an additional seat apart, and 4.0% if they are in opposite corners of the clinic. This probability did not account for other factors such as the participants’ race and the two structural parameters, GWESP and GWDegree. For example, if both participants were Hispanic and they had a relationship with another participant in common, the probability of forming a link would be 22%.

Describing and Modeling Living Donation Requests as Contagious Behavior

Using a contagion model, we examined whether participants who had requested a living donation and discussed transplantation in-center influenced other participants to request a living donation (Figure 1). Over the course of the study, 13 (36%) of the 35 susceptible participants requested living donation (see Figure 1, Figure 2, and Table 3). Although most participants (85%) formed links and some (39%) discussed transplantation (Table 3), most participants (61%) requested a donation before forming a relationship. Five participants (39%) requested a transplant after being exposed to a network member who had requested a transplant, whereas only two of the participants (15%) requested a donation after discussing transplantation in-center. A similar proportion of participants who never made a living donation request were exposed to a network member who requested a transplant and/or discussed transplantation.

Goodness of Fit and Sensitivity Analyses
We inspected the STERGM for goodness of fit and found no significant deviation between the simulated models and the observed data. Sensitivity analyses shows the robustness of our transplant discussion homophily model (Supplemental Table 3) because the positive trend to transplant-discussion homophily persisted even if 10% and 20% of the participants incorrectly answered the questionnaire about discussing transplantation.

**Discussion**

Hemodialysis patients form relationships with other patients who sit close to them, especially if they are of similar ethnicity and have similar transplant behaviors. The increase of in-center patient transplant discussions and living donation requests by the hemodialysis clinic social network members was not because of social contagion. Instead, participants who requested a living donation were more social, more likely to form a relationship, and preferentially formed relationships with other participants who discussed transplantation as a function of health-behavior homophily.

Requesting a living donation did not spread like a social contagion, health-behavior homophily is a significant finding because it can be used to create future network interventions within the hemodialysis clinic to improve access to living donor transplantation. Health-behavior homophily improves the efficacy of network interventions (31) because people are more willing to adopt a behavior if they know that people similar to them have also adopted that behavior (32). These social network interventions should cause patients to spread the intervention from one to another via their relationships and the intervention will go “viral” via social contagion, and its adoption will grow exponentially (32, 33). The hemodialysis clinic staff can facilitate this intervention because many of the participants who request a living donation discuss transplantation with the staff.
One example of a clinic-based network intervention would be to train participants who discuss transplantation in-center to help each other navigate the transplant process, discuss the best ways to request a living donation, and identify other potential living donors if they have already made a request (34). Furthermore, if those who have not discussed transplantation with other patients are seated among a majority of other participants who discuss positive transplant information, this could induce homophily-based communication (5, 6). Seating and shift assignment seem to be very influential in forming relationships because only ~10% of the interactions occurred in the waiting room. Additionally, future research is necessary to identify how to tailor this transplant network intervention to the ethnic homophily that the Hispanic patients exhibited.

Ethnic homophily is not uncommon (8, 17, 18) and can be attributed to similar beliefs, behaviors, experiences, appearances, and language. Speaking only Spanish may have contributed to ethnic homophily; however, it was not a significant variable in our homophily model probably because English-speaking Hispanic participants were also fluent in Spanish. Thus, Hispanic Spanish-speaking participants would preferentially form relationships with other Hispanic participants who only spoke Spanish as well as with those who were bilingual. In our previous study of network participation in this cohort (1), we found no ethnic differences in network participation. This is because although Hispanic participants were less likely to form links, they were likely to form a link with another Hispanic participant if present on the shift, and Hispanic participants were present on all shifts.

Unlike previous research (1), which found sex differences in network participation, we did not find sex differences in the formation of links. However, the use of a dynamic longitudinal model, which is superior at link prediction to our previous cross-sectional model (1), is
underpowered at predicting isolates (26). More research is needed to understand the factors that are associated with not participating in the hemodialysis social network, especially given that fewer isolates requested a living donation as compared to network participants and social isolation is a maladaptive coping mechanism (35).

This study is not without its limitations. The major limitation is that this is a single center study with a small sample. The sample size was small because this longitudinal observational cohort study was set in a newly opened twelve-station clinic that started with only a few patients. This allowed us to observe the formation of new networks and the appearance and spread of behaviors (17). Also, because of the size of the clinic, most patients were under the care of a single nephrologist, which avoided differences in nephrologists’ practices towards transplantation (36).

Another limitation is that we may not have observed all participant interactions in the clinic as evidenced by one participant who reported discussing transplantation in-center but was not observed interacting with other participants. Further, documenting simple communication behavior may have identified relationships that did not result in information transfer, especially because the length of conversations was not assessed here. To understand the content of conversation, we relied on self-reported data based on participants’ recall of requesting a transplant or discussing transplantation with other participants. We assume that participants discussed positive transplant information; however, it is possible participants shared negative experiences as well because none of the participants received a living donor transplant. Additionally, although our questionnaire was designed to avoid desirability bias, bias is always possible when people are repeatedly asked the same question (25). To address these limitations, a
multi-center study is currently underway, with special attention to what participants discuss and with whom.

In conclusion, our study demonstrates the influence of seating assignment and transplant related health behaviors on social network formation among in-center dialysis patients and demonstrates that there is potential for social network interventions to improve health behaviors as a function of sociality and health-behavior homophily.

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| Table 1. Glossary of Terms |
|---------------------------|
| **Term** | **Definition** |
| **Social Network Theories** | |
| Social Contagion | "The spread of affect or behaviour from one crowd participant to another; one person serves as the stimulus for the imitative actions of another." (16) This includes sharing information, imitating behaviors, and enforcing norms. |
| Homophily | The tendency for people to seek out or be attracted to those who are similar to themselves. |
| Sociality | The tendency for people to form relationships. *Commonly referred to as extroverted.* |
| Clustering | The tendency for network members to share mutual relationships. For example, if member A is linked to member B and member C, it is likely member B and C are also linked. This is also known as transitivity. |
| Centralization | The tendency for a few members to have many links while most other members have one or two links. For example, if member A joins a network and member C has 5 links and Member B has 1 link, member A would preferentially form a link with Member C. This is known as preferential attachment. |
| **Social Network Analysis** | |
| Link | A social network term for a relationship between two network members. |
| Edges | Another term for a link or relationship used in graph theory. |
| Degree | The number of relationships (links) a network member has. |
| Density | How many links exist between members of a social network out of the possible number of links that could exist among members. |
| Dense Network | In a dense network, most or all the members are linked to the other members. |
| Sparse Network | In a sparse network, most members are not linked to the other members. |
| STERGM | A separable temporal exponential random graph model analyzes the network as a multivariate observation with a link as the dependent variable. The observed network is then compared to 100,000 randomly generated Markov random graphs (networks) using maximum pseudo-likelihood estimation and Monte Carlo maximum likelihood estimates (MC MLE) (26). |
| GWESP | Geometrically weighted edgewise shared partner weights the probability of two members forming a relationship based the number of relationships with other members they have in common. This parameter is used in STERGMs to approximate clustering within the network. |
| GWDegree | Geometrically weighted edgewise degree weights the probability of network member forming a relationship based on the number of relationships they already have (number of relationships = degree). This parameter is used in STERGMs to approximate centralization within the network. |
| **Table 2. Demographic, Transplant, and Dialysis Variables** | \( N = 46 \) (%) |
|-------------------------------------------------------------|------------------|
| **Age and Sex**                                             |                  |
| Age mean (SD)                                               | 55 (14)          |
| Female Sex                                                  | 19 (41)          |
| **Language**                                                |                  |
| English                                                     | 36 (78)          |
| Spanish                                                     | 10 (22)          |
| **Race**                                                    |                  |
| White                                                       | 10 (22)          |
| Black                                                       | 15 (33)          |
| Hispanic/Latino                                             | 17 (37)          |
| Multi-Ethnic                                                | 4 (9)            |
| **Education**                                               |                  |
| Grade 9 or Less                                             | 11 (24)          |
| High School                                                 | 27 (59)          |
| College or Higher                                           | 8 (17)           |
| **Eligibility, Wanting, and Asking for a Transplant**       |                  |
| Eligible for Transplant                                      | 37 (80)          |
| Wants a Living Donor Kidney Transplant                       | 39 (85)          |
| Waitlisted Before Joining the Study                         | 8 (17)           |
| Waitlisted \( (n = 10) \) or Received a Deceased Donor Transplant \( (n = 7) \) by the end study | 17 (37)          |
| **Hemodialysis Shift Assignment**                           |                  |
| Monday, Wednesday, Friday (MWF)                             | 32 (61)          |
| Tuesday, Thursday, Saturday (TTS)                           | 14 (39)          |
| **Vintage**                                                  |                  |
| <1 Year                                                     | 29 (63)          |
| ≥1 Year                                                     | 17 (37)          |
| **Nephrology Providers \( N = 3 \)**                        |                  |
| Same Provider                                               | 42 (91)          |
### Table 3. Transplant Waitlist Status, Network Participation, Transplant Discussions, and Living Donor Requests

|                              | Infected | Susceptible | Did Not Request a Donation |
|------------------------------|----------|-------------|----------------------------|
| **Waitlist and Transplant Status** |          |             |                            |
| Wants a Living Donor Transplant | 11 (100) | 13 (100)    | 15 (68)                    |
| On the Waitlist at Beginning of Study | 2 (18)  | 4 (31)      | 2 (9)                      |
| On the Waitlist or Received a Deceased Donor Transplant by the End of Study | 6 (55)  | 7 (54)      | 4 (18)                     |
| Received a Deceased Donor Transplant | 2 (18)  | 4 (31)      | 1 (5)                      |
| **HD Social Network and Discussions** |          |             |                            |
| Members of the HD Social Network | 10 (91)  | 11 (85)     | 11 (50)                    |
| Discussed Transplant with other participants | 8 (73)  | 5 (39)      | 2 (9)                      |
| Discussed Transplant with Staff | 8 (73)  | 8 (62)      | 5 (24)                     |
| **Exposure and Living Donor Requests** |          |             |                            |
| Exposed to at Least One Member Who Discussed Transplant | N/A      | 2 (15)      | 8 (36)                     |
| Exposed to at Least One Member Who Requested a Transplant | N/A      | 5 (39)      | 9 (41)                     |
| **Family and Friends Transplant Discussions** |          |             |                            |
| Discussed with Significant Other | 6 (55)  | 7 (54)      | 8 (37)                     |
| Discussed with Children | 7 (64)  | 9 (69)      | 9 (41)                     |
| Discussed with Other Family | 8 (73)  | 11 (85)     | 13 (59)                    |
| Discussed with Friends | 6 (55)  | 8 (61)      | 5 (26)                     |

Note: N/A not applicable as they were already “infected.” a. p value is from a chi square test unless otherwise indicated. b. Fisher’s exact test.
Table 4. STERGM models for link prediction

|                           | Model 1: Full Model |                           | Model 2: Discussed Transplant |                           | Model 3: Requested a Donation Model |
|---------------------------|---------------------|---------------------------|-------------------------------|---------------------------|-------------------------------------|
|                           | $\beta$ [SE], $p$ value |                           | $\beta$ [SE], $p$ value |                           | $\beta$ [SE], $p$ value |
| **Structural Variables**  |                     |                           |                               |                           |                                     |
| Edges                     | -8.57 [1.88], <0.001 |                           | -7.80 [1.79], <0.001         |                           | -7.99 [1.88], <0.001               |
| GWDegree (0.25)           | -0.75 [0.34], 0.03   |                           | -0.91 [0.33], 0.006          |                           | -0.90 [0.34], 0.007               |
| GWESP (0.55)              | 0.80 [0.18], <0.001  |                           | 0.78 [0.18], <0.001          |                           | 0.77 [0.18], <0.001               |
| **Dialysis Clinic Variables** |                     |                           |                               |                           |                                     |
| TTS (Sociality)           | 0.37 [0.18], 0.04    |                           | 0.41 [0.18], 0.02            |                           | 0.33 [0.18], 0.06                 |
| TTS (Homophily)           | 3.42 [0.99], <0.001  |                           | 3.42 [0.99], <0.001          |                           | 3.25 [1.02], <0.001               |
| Average Seating Distance  | -0.30 [0.10], 0.002  | -0.28 [0.10], 0.003       | -0.30 [0.10], 0.003          |                           |                                     |
| (per seat; Euclidean)     |                     |                           |                               |                           |                                     |
| **Patient Attributes**    |                     |                           |                               |                           |                                     |
| Age                       |                     |                           |                               |                           |                                     |
| Year (Sociality)          | 0.01 [0.01], 0.19    |                           | 0.01 [0.01], 0.24            |                           | 0.01 [0.01], 0.17                 |
| Year (Homophily)          | -0.01 [0.01], 0.42   | -0.01 [0.01], 0.31        | -0.01 [0.01], 0.49           |                           |                                     |
| Sex                       |                     |                           |                               |                           |                                     |
| Female Sex (Sociality)    | -0.34 [0.32], 0.29   | -0.29 [0.31], 0.34        | -0.29 [0.31], 0.34           |                           |                                     |
| Sex (Homophily)           | 0.14 [0.27], 0.72    | 0.17 [0.38], 0.66         | 0.17 [0.40], 0.68            |                           |                                     |
| **Race**                  |                     |                           |                               |                           |                                     |
| White (Sociality)         |                     | REF                       | REF                           | REF                       | REF                                 |
| White (Homophily)         | -0.37 [1.18], 0.75   |                           | -0.46 [1.18], 0.70           |                           | -0.40 [1.16], 0.73                |
| Black (Sociality)         | 0.22 [0.49], 0.64    |                           | 0.11 [0.48], 0.82            |                           | 0.22 [0.48], 0.64                 |
| Black (Homophily)         | 0.37 [0.69], 0.60    |                           | 0.34 [0.68], 0.62            |                           | 0.32 [0.68], 0.64                 |
| Hispanic (Sociality)      | -0.93 [0.46], 0.04   |                           | -0.96 [0.46], 0.04           |                           | -0.93 [0.46], 0.04                |
| Hispanic (Homophily)      | 2.31 [0.69], <0.001  | 2.31 [0.66], <0.001       | 2.19 [0.68], 0.001           |                           |                                     |
| Multi (Sociality)         | 1.21 [0.53], 0.02    |                           | 0.97 [0.52], 0.06            |                           | 1.45 [0.52], 0.03                 |
| Multi (Homophily)         | -0.21 [1.33], 0.87   | 0.01 [1.38], 0.99         | -0.43 [1.34], 0.75           |                           |                                     |
| **Transplant Attributes** |                     |                           |                               |                           |                                     |
| Discussed Transplant with |                     |                           |                               |                           |                                     |
| other patients (sociality)| 0.23 [0.29], 0.41    |                           | 0.41 [0.24], 0.08            |                           |                                     |
| Discussed Transplant with |                     |                           |                               |                           |                                     |
| other patients (homophily)| 0.66 [0.35], 0.06    |                           | 0.64 [0.31], 0.04            |                           |                                     |
| Requested a Donation      |                      |                           |                               |                           |                                     |
| (sociality)               | 0.49 [0.26], 0.06    |                           | 0.49 [0.24], 0.04            |                           |                                     |
| Requested a Donation      |                      |                           |                               |                           |                                     |
| (homophily)               | -0.23 [0.34], 0.50   |                           | -0.03 [0.34], 0.93           |                           |                                     |
| **Model factors**         |                     |                           |                               |                           |                                     |
| Null deviance,            | 14187 df 10234       |                           | 14187 df 10234               |                           | 14187 df 10234                     |
| Residual deviance         | 474, df 10213        |                           | 479, df 10215                |                           | 478, df 10215                      |
| AIC, BIC                  | 517, 669            |                           | 517, 654                     |                           | 516, 653                           |

Table 4. STERGM models for link prediction. This is the Separable Temporal Exponential Random Graph Model of the variable that are associated with the formation of the hemodialysis
clinic social network. We report the $\beta$ coefficients, which are the log-odds of the formation of link and the standard error of the coefficients as well as the $p$ value. Edges is the log-odds of a participant forming a link with another participant independent of the other variables and represents the intercept of the model. Geometric Weighted Degree (GWDegree) is the log-odds of a participants with fewer links (i.e., lower degree) to form a new link compared those participants with links (i.e., higher degree). Geometric edgewise shared pairs (GWESP) are the log-odds that participants are more likely to link if they already share a link in common with another participant. These effects geometrically diminish as the number of shared links decrease. Sociality represents the propensity of a participant forming a link with any other participant, Homophily represents the propensity of a participant to form a link with another participant with the same attribute. Tuesday, Thursday, Saturday dialysis shift (TTS). Akaike information criterion (AIC). Bayesian information criterion (BIC).
Figure 1. Formation of the Network, Transplant Discussions, and Living Donor Requests over Time.

The key for Figure 1 shows what each symbol and line represent as well as some examples of the social network theories: social contagion, homophily, and sociality. For Figure 1, each panel represents a time point. Times 1 thru 10 are displayed. The positions of the shapes are based on the multidimensional scaling algorithm to improve network visualization and do not represent the seating of the participants in the clinic. Each of the 10 frames represents a 3-month period with the blue arrows showing the progression of time. Within each frame is the social network during that period. Within the frame M,W, F participants are represented by a triangle and T,T,S participants are represented by a circle. The larger shapes represent the participants who discussed transplantation in-center. Black shapes represent the participants who requested a living donation before starting the study. White shapes represent the “susceptible” participants who have not requested a living donation. If participants request a living donation after joining the study, they are considered “infected” and their shape becomes red. A black line between two shapes represents a relationship (link). Blue arrows denote the passage of time.

Figure 2. Growth curves of in-center transplant discussions and requesting a living donation.

In the figure key, “in-center participants” is the total number of participants who were admitted to the clinic at that time point. “Asked before joining” are participants who requested a living donation before joining the study. “Asked after joining” are participants who were “infected” and requested a living donation after joining the study. In-center discussions are the number of participants who requested a living donation. The figure shows the growth curves of the clinic population, the number of participants who had in-center transplant discussions, and the number of participants who requested a living donation over the study period.

Figure 3. Hemodialysis Unit Layout and Probability of Forming a Link Based on the Seating Distance.

This figure is a representation of the seating layout of the hemodialysis clinic. There are twelve dialysis stations. The probability of a participant in Seat 1 forming a relationship and discussing transplantation with a participant in each seat is written in the representation of the seat. The nurse’s station is in the center of all the chairs and was where the observations were made. The dimensions of the treatment area are 44 feet (13.4 meters) by 35 feet (10.7 meters); the waiting room, not shown, is directly outside the treatment area.
Social Network Figure 1. Key

Shift Assignment (Type of Shape)
- M, W, F
- T, T, S

Size of the Shape Represents In-Center Transplantation Discussions
- Large black circle: Discussed transplantation
- Large white circle: Did not discuss transplantation

Color Represents Living Donor Requests
- Black triangle: Made a request before
- Red triangle: Made a request after
- White triangle: Has not made a request

Social Contagion
A participant who discusses transplantation and has made a request (large black circle) influences another participant who discusses transplantation but has not made a request (large white circle) to make a request (large red circle at Time 2).

Homophily
A participant who discusses transplantation and made a request (large black circle) prefers to form a link with another participant who similarly discusses transplantation and made a request. Conversely, a participant who does not discuss transplantation and has not made a request (small white circle) prefers to form a link with a participant who is similar.

Sociality
Participants who discuss transplantation and made a request (large black circle) are more social and will form links with other participants regardless of whether they have discussed transplantation and made a request (large black circle) or do not discuss transplantation and have not made a request (small white circle).
Figure 1
Figure 3

- Seat 1 (REF) 10.8%
- Seat 2 13.8%
- Seat 3 10.8%
- Seat 4 8.4%
- Seat 5 6.3%
- Seat 6 5.7%
- Seat 7 5.0%
- Seat 8 4.2%
- Seat 9 4.0%
- Seat 10 4.5%
- Seat 11 4.8%
- Seat 12 5.0%

Distance:
- 35 feet (10.7 meters)
- 44 feet (13.4 meters)