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Hemodialysis Clinic Social Networks, Sex Differences, and Renal Transplantation

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This study describes patient social networks within a new hemodialysis clinic and models the association between social network participation and kidney transplantation. Survey and observational data collected between August 2012 and February 2015 were used to observe the formation of a social network of 46 hemodialysis patients in a newly opened clinic. Thirty-two (70%) patients formed a social network, discussing health (59%) and transplantation (44%) with other patients. While transplant-eligible women participated in the network less often than men (56% vs. 90%, $p = 0.02$), women who participated discussed their health more often than men (90% vs. 45.5%, $p = 0.02$). Patients in the social network completed a median of two steps toward transplantation compared with a median of 0 for socially isolated patients ($p = 0.003$). Patients also completed more steps if network members were closely connected ($\beta = 2.23$, 95% confidence interval [CI] 0.16–4.29, $p = 0.03$) and if network members themselves completed more steps ($\beta = 2.84$, 95% CI 0.11–5.57, $p = 0.04$). The hemodialysis clinic patient social network had a net positive effect on completion of transplant steps, and patients who interacted with each other completed a similar number of steps.

Abbreviations: CI, confidence interval; DPTQ, Dialysis Patient Transplant Questionnaire; ESRD, end-stage renal disease; MWF, Monday, Wednesday, Friday; TTS, Tuesday, Thursday, Saturday; UNOS, United Network of Organ Sharing database

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Introduction

A growing body of literature demonstrates the impact of social networks on the diffusion of healthful and unhealthful behaviors in chronic conditions such as obesity (1), alcoholism (2), and smoking (3). Interventions targeting influential members of social networks can change health behavior (4,5), and differences in social networks (6–9) may contribute to persistent inequities in access to and use of transplantation among women and ethnic minorities (10–18).

In-center hemodialysis offers a unique setting for studying the formation and impact of social networks on transplant outcomes. First, in-center hemodialysis is the predominant treatment for end-stage renal disease (ESRD) in the United States (19). Second, hemodialysis is performed in a group setting amenable to the formation and examination of social networks (20), which may facilitate the diffusion of transplant-related information, attitudes, and behaviors. Little is known about the function and structure of hemodialysis patient social networks (6–9); however, research examining the social support and information provided by clinic staff and other patients (21–26) highlights the importance of social networks within the hemodialysis clinic.

For example, patients often do not receive sufficient information regarding kidney transplantation (6,12,27–29) and rely on other hemodialysis patients and clinic staff for their health (26) and transplant-related information (6,8). Patients who receive positive and factual information from members of their social network are more likely to be evaluated for transplantation, whereas patients who are exposed to bad transplant outcomes are less likely to want a kidney transplant (9,29,30). Further, patients who rely heavily on support from the hemodialysis clinic may not pursue kidney transplantation for fear of losing that support system (21,31).

Social network analysis extends beyond examining social support to actually modeling the attributes of the individual (ego) by their relationships (links) and attributes of other individuals (alters or members) within the network (32). A patient's position within the network can be measured by the number of links with other patients (alters), centrality (measured by eigenvector centrality), and how interlinked network members are to each other (measured by the clustering coefficient) (33–36).

The goals of this study were to characterize which patients form social networks in an ethnically and racially diverse urban hemodialysis clinic and to understand how these networks influence knowledge, attitudes, and behaviors toward transplantation. We used social network methods to examine the association of patient progress through the transplant workup with their network position and the progress and position of other network members. We combined these network variables with demographic variables associated with access to transplantation such as age (13), race (11–13), sex (16,17), and religious beliefs (37) to improve our understanding of how hemodialysis clinic social networks affect access to kidney transplantation.

Materials and Methods

Setting

Between August 2012 and February 2015, we conducted a prospective observational cohort study of the formation and role of social networks in a newly opened, 12-station hemodialysis clinic in a large city in the Mid-Atlantic region of the United States.

Study eligibility and participation

Patients were eligible to participate if they had ESRD, spoke English or Spanish, were 18 years of age or older, and were expected to be in the clinic for longer than 3 months. The Temple University Institutional Review Board approved the study protocol, and written informed consent was obtained from all patient participants.

Measurement

The paper-and-pencil Dialysis Patient Transplant Questionnaire (DPTQ) was used (see Data S1). This previously validated, 47-item instrument takes 30 min to complete and is written at a sixth-grade literacy level. Data associated with kidney transplantation (marital and current living status, employment, religious affiliation), as well as transplant preferences and attitudes (15,17,38), were collected by using the DPTQ. A single 5-point Likert-type item assessed self-reported health (1, *excellent*; 5, *poor*). Two items asked patients whom they relied on for health and kidney transplant information. Patients could identify as many people as they desired from outside (e.g. spouse, significant other, friends, family, religious community, primary care physician) and within the hemodialysis clinic (e.g. nephrologist, hemodialysis staff, social worker, other patients). Surveys were administered within the first 3 months of admission to the clinic or when the patient was clinically stable (baseline) and then repeated every 3 months to determine the time between enrollment in the clinic and having conversations with other patients.

Assessing patient social networks

To eliminate the potential for recall and social desirability bias (39) in patient self-reported social interactions, trained research staff observed and documented patient interactions. Staff observed and recorded patient interactions from the centrally located nurses' station within the treatment area on a weekly or biweekly basis, in the waiting area, and outside the clinic while patients waited for transportation. Patients were neither encouraged nor discouraged to communicate with each other. Consistent with protocols developed specifically for this setting, all patient interactions in the form of verbal communication between patients from a simple greeting to a long conversation were logged by patient ID and date. Each patient was observed for no more than 5 min at a time. Seventy-three observations were documented, 43 (60%) of which were among the same participants on different occasions. Staff did not record the content of patient conversations; these data were collected from the DPTQ. The charge nurse assigned patients to either a Monday, Wednesday, Friday (MWF) or a Tuesday, Thursday, Saturday (TTS) schedule based on patient preference and availability; and seating assignment was based on clinical judgment and dialysis duration. Initial seating assignments and subsequent changes in seating and/or shift were recorded.

Transplant eligibility and steps toward transplantation

Patient eligibility for transplantation was abstracted from medical records and confirmed with the transplant center and the United Network of Organ Sharing database (UNOS). Absolute contraindications to kidney transplant evaluation were active malignancy, severe inoperable cardiac or peripheral vascular disease, and age older than 80 years. Progress along the path to kidney transplantation was determined via chart review by using a schema developed by Sullivan et al (40): (1) suitability for referral to transplant center, (2) interest in transplantation, (3) referral call to transplant center, (4) first visit to transplant center, (5) transplant center workup, (6) workup complete, (7) active on the list, (8) successfully received a kidney transplant.

Statistical analyses

Bivariate comparisons were made on demographic, health, and attitudinal variables obtained from the DPTQ that have been shown to influence completion of transplant steps (11–13,16,17). Fisher's exact tests and χ^2 tests were used to test for associations between categorical variables as appropriate. Mean differences were assessed using two-tailed two-sample t tests. For data that substantially deviated from normality, bivariate associations were analyzed by using the Mann–Whitney U test.

Figure 1 depicts the static social network graph constructed using each patient as a node and each patient–patient interaction as an undirected link, which assumes each interaction is reciprocal. The layout algorithm used to create Figure 1 does not represent the physical distance between patients; rather, it clusters patients who share similar links. We calculated the clustering coefficient and eigenvector centrality from the interaction data (34,41). Treating MWF and TTS as discrete networks and recalculating the centrality and clustering coefficient yielded no change in the MWF results and no change in the TTS clustering coefficients; however, centrality was nearly equivalent, meaning that no dominant central patient emerged. Thus, for the purpose of the regression analyses, the data were analyzed as one large network.

To examine the effect that members of patients' first-degree network (i.e. alters) had on their progress toward transplantation, we calculated the mean proportion of steps completed by the members of each patient's network. Because patients further along in the workup at enrollment had fewer steps to complete, we used the proportion of steps completed to compare patients who enrolled at different steps of the workup process. We calculated the proportion of steps completed by dividing the number of steps completed during the study period by the total possible number of steps that could be completed based on the patient's starting step at enrollment.

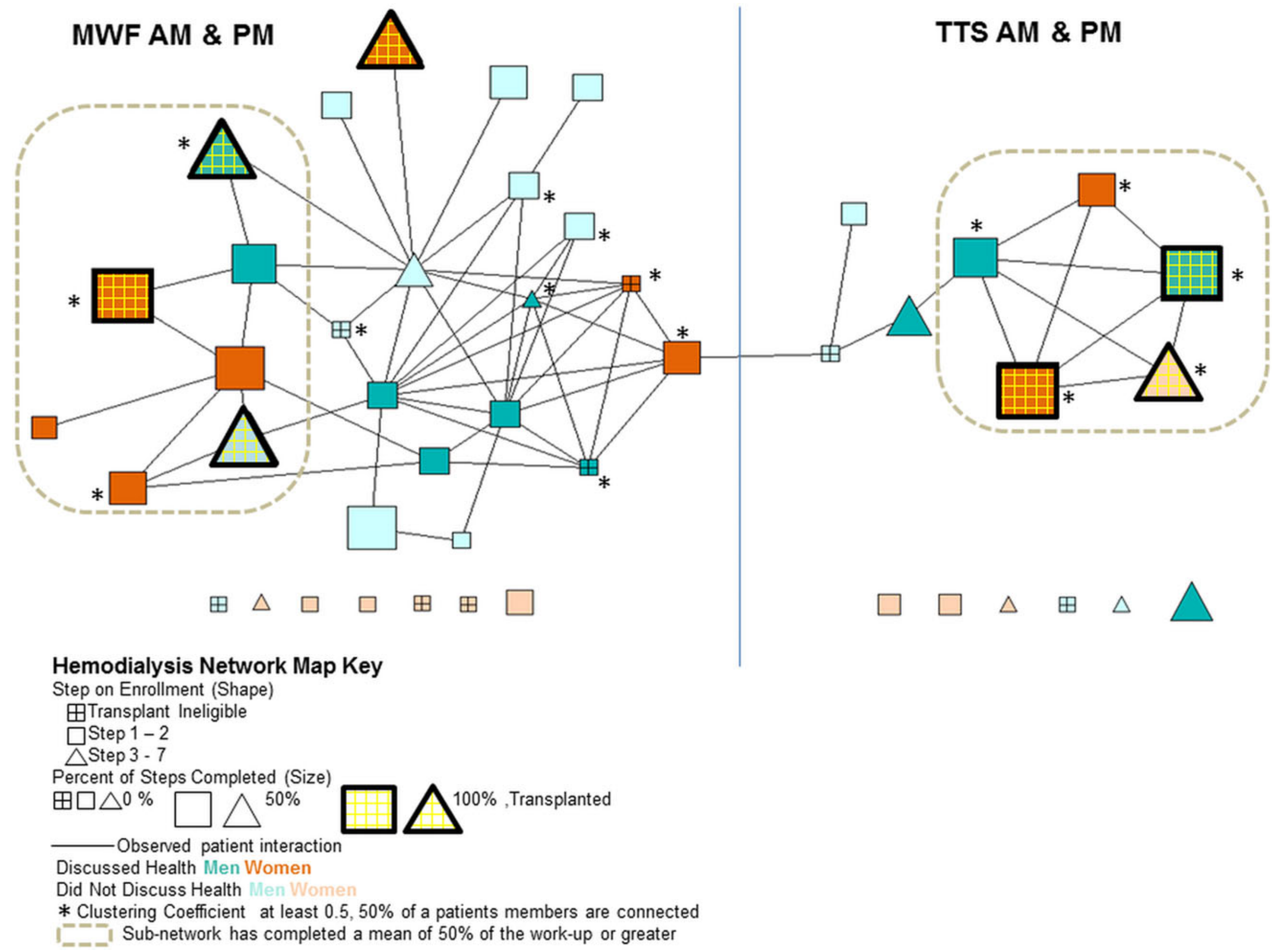

Figure 1: A static network graph of the observed hemodialysis (HD) patient interactions in a newly formed HD clinic. Each node represents a patient (n = 46). Each line (link) between the nodes represents an observed interaction. Nodes that are not linked to other nodes are the patients who were not observed interacting with each other (isolates). The patients observed interacting with each other form one component composed of 126 links, a density of 0.06, and a median of three links per patient (IQR 1.5–4.5). Patients formed links within their shifts as well as outside of their shifts. Monday, Wednesday, Friday (MWF) morning (AM) and afternoon (PM) shifts formed one large subcomponent. The TTS AM and PM shifts were initially third shift MWF and thus the link between the different schedules. The two shifts are separated by the blue line. Below the linked component are the isolates from that shift. Dark orange nodes represent women who discussed their health with other patients, and light orange nodes represent women who did not discuss health. Dark blue represents men who discussed their health with other patients, and light blue represents those who did not discuss health. The majority of isolates are women. One patient reported discussing health with other patients but was not observed participating in the social network and is grouped among the isolates. A square represents a patient at step 2 of the transplant workup, and a triangle represents a patient who was at step 3 or greater on study enrollment. Squares with a cross identify patients who were ineligible for transplantation. The size of the node correlates with the percent of the transplant workup completed: the larger the node, the greater amount of workup completed. Patients who were transplanted also have a yellow check. Nodes with an asterisk have a clustering coefficient ≥0.5, meaning that at least 50% of their network's alters are connected to each other. The most central patients are not only located in the center of the network but also tend to have many links ($R = 0.83$, $p < 0.001$, not shown in the tables). Subnetworks in which the mean completion of steps is ≥50% are encircled with a tan dashed line.

Patients who completed their workup and received a transplant were scored as 1.00, 0.50 if half of the steps were completed, and 0.00 if no steps were completed. If during the workup process the patients were deemed ineligible for transplant, they were scored by the highest step completed. Patients who were transplant ineligible on enrollment were scored as 0.00 and included in the calculation of mean steps completed by network members to examine their potential influence on other patients.

We examined associations between demographic, survey (Tables 1 and 2), and network variables, with the number of steps completed by those who were at step 2 (interest in transplantation) on enrollment by using linear regression with a randomization test. The randomization test is recommended in social network analyses because the social network variables cannot be presumed to be independent (42). To counter the increased risk of type 1 error, the randomization tests uses a

Table 1: Demographic variables associated with network participation

	Isolates, n (%)	Networked, n (%)	Total	p value[2]
	14 (30.4)	32 (69.6)		
Age, years ± SD	55 ± 14	56 ± 15	55 ± 14	0.74[1]
Sex				0.04
Men	5 (35.7)	22 (68.8)	27 (58.7)	
Women	9 (64.3)	10 (31.2)	19 (41.3)	
Race/ethnicity				0.61
White	5 (35.7)	5 (15.6)	10 (21.7)	
Black	4 (28.6)	11 (34.4)	15 (32.6)	
Hispanic	4 (28.6)	10 (40.6)	14 (37.0)	
Multiethnic	1 (7.1)	3 (9.4)	4 (8.7)	
Marital status				0.79
Lives with Significant other	6 (42.9)	11 (34.4)	17 (37.0)	
Divorced/separated	6 (42.9)	14 (43.8)	20 (43.5)	
Never married	2 (14.3)	7 (21.9)	9 (19.5)	
Education				0.33
Grade 9 or less	2 (14.3)	9 (28.1)	11 (23.9)	
High school	8 (57.1)	19 (59.4)	27 (58.7)	
Some college	4 (28.6)	4 (12.5)	8 (17.4)	
Employment				0.77
Employed	2 (14.3)	4 (12.6)	6 (13.0)	
Unemployed	2 (14.3)	2 (6.2)	4 (8.6)	
Retired	4 (28.6)	8 (25.0)	12 (26.1)	
Disabled or other	6 (42.9)	17 (56.2)	23 (52.2)	
Religion				0.97
Christian	10 (71.4)	23 (71.9)	33 (71.7)	
Other	4 (28.6)	9 (28.1)	13 (28.3)	
ESRD diagnosis				0.79
Diabetes	7 (50)	15 (46.9)	22 (47.8)	
Hypertension	3 (21.4)	4 (12.5)	7 (15.2)	
Glomerulonephritis	2 (14.3)	5 (15.6)	7 (15.2)	
Other	2 (14.3)	8 (25)	10 (21.7)	
Dialysis vintage				0.58
<1 year	8 (57.1)	21 (65.6)	29 (63.0)	
≥1 year	6 (42.9)	11 (34.4)	17 (37.0)	
Dialysis schedule				0.23
Monday, Wednesday, Friday (MWF)	8 (25)	24 (75)	32 (69.6)	
Tuesday, Thursday, Saturday (TTS)	6 (42.9)	8 (57.1)	14 (30.4)	
Self-reported health				0.48
Excellent	1 (7.1)	0 (0.0)	1 (2.2)	
Very good	2 (14.3)	2 (6.3)	4 (8.7)	
Good	3 (21.4)	10 (31.3)	13 (28.3)	
Fair	6 (42.9)	16 (50.0)	22 (47.8)	
Poor	2 (14.3)	4 (12.5)	6 (13.0)	

[1] p values are calculated by t test.

[2] p values are reported for Pearson χ^2 test.

bootstrapping method, which samples 10 000 random permutations of the observed network variables to estimate standard errors of R^2 values and slope coefficients that can then be used for statistical inference (43). We performed univariate linear regressions with a randomization test followed by a multiple linear regression with a randomization test combining network variables and survey variables with a p-value <0.20. We selected our multiple regression model based on the significance of R^2 and the regression coefficient, as well as parsimony. We report the adjusted R^2.

We inspected the model residual plots for normality and homoscedasticity. The dependent variable, number of steps completed for patients starting at step 2, was approximately normally distributed (Shapiro–Wilk p = 0.07). SPSS (44) was used for the descriptive and bivariate analyses and to examine residuals. UCINET (43) was used for the network analyses and randomization tests. For all tests, $p < 0.05$ was considered statistically significant.

Results

Study participation

Among the 63 patients who received hemodialysis in this clinic during the study period, 14 were ineligible to

Table 2: Differences in attitudes, behaviors, discussions, and steps toward kidney transplantation

	Differences between patients in and out of network, n = 46			Sex differences in networked patients, n = 32		
	Isolates n = 14	In network n = 32	p value	Women n = 10	Men n = 22	p value
Attitudes and behaviors toward transplantation, n (%)						
Would accept living-donor or deceased-donor kidney transplant	10 (71.4)	32 (100)	0.006[1]	10 (100)	22 (100)	n/a
Asked for LDKT	3 (21.4)	21 (65.6)	0.01[1]	8 (80)	13 (61.9)	0.43[1]
Health and transplant discussions with patients and staff, n (%)						
Discuss health with other patients[3]	1 (7.1)	19 (59.4)	0.001[1]	9 (90)	10 (45.5)	0.02[1]
Discuss transplantation with other patients[3]	1 (7.1)	14 (43.8)	0.018[1]	6 (60)	8 (36.4)	0.27[1]
Discuss health with clinic staff	2 (14.3)	24 (75)	<0.001[1]	7 (70)	17 (77.3)	0.68[1]
Discuss health with nephrologist	9 (64.3)	29 (90.6)	0.044[1]	9 (90)	20 (90.9)	1.00[1]
Potential transplant candidate	9 (64.3)	28 (87.5)	0.11[1]	9 (90)	19 (86.4)	1.00[1]
MWF[4] n = 32[5], n = 21[6]	5 (62.5)	21 (87.5)	0.15[1]	6 (85.7)	15 (88.2)	1.00[1]
TTS[4] n = 14[5], n = 8[6]	4 (66.7)	7 (87.5)	0.54[1]	3 (100)	4 (80)	1.00[1]
Steps toward transplantation among transplant-eligible patients (n = 37)				Transplant-eligible patients (n = 28)		
Step on enrollment, median (IQR)	2 (2–5.5)	2 (2–4.25)	0.66[2]	2 (2–4)	2 (2–5)	0.97[2]
Step at the end of study, median (IQR)	3 (2.5–7.0)	5.5 (4–7.75)	0.048[2]	7 (5–8)	5 (4–7)	0.15[2]
Steps taken, median (IQR)	0 (0–1.5)	2 (2–3.75)	0.003[2]	2 (2–3.75)	2 (2–2.5)	0.16[2]
MWF[4] (IQR) n = 26[5], n = 21[6]	0 (0–1)	2 (2–3)[7]	0.008[2]	3 (1.75–5.25)	2 (2–2)	0.13[2]
TTS[4] (IQR) n = 11[5], n = 7[6]	1 (0.25–2.5)	3 (1–6)[7]	0.11[2]	3 (1–3)	3 (1.25–5.5)	1.0[2]
Received kidney transplant, n (%)	0 (0)	7 (25)	0.16[1]	4 (44.4)	3 (15.8)	0.17[1]

[1] p values are reported for Pearson χ^2 or Fisher's exact test.

[2] p value is Mann–Whitney U test as the dependent variable substantially deviates from normality.

[3] One patient reported having discussions with other patients but was not observed.

[4] MWF represents patients on the Monday, Wednesday, Friday shift; TTS represents patients on the Tuesday, Thursday, Saturday shift.

[5] The number of patients on the respective shift used in the bivariate analysis of participating in the social network.

[6] The number of patients on the respective shift participating in the social network used in the bivariate analysis of sex.

[7] There is no significant difference in completed steps between MWF and TTS, p = 0.43.

participate; two (3%) spoke neither English nor Spanish, and 12 (19%) were admitted for less than 3 months. Of the remaining 49 patients, 46 (94%) completed the baseline survey and had at least 3 months of follow-up. Surveys were completed during the hemodialysis treatment and were either self-administered (17%) or administered by a member of the research team (83%). Forty (89%) patients completed at least one follow-up survey. Surveys were administered in English (70%) and Spanish (30%).

Patient demographics

Participant mean age was 55 years (range 23–87, standard deviation 14 years). More than half of the patients were male (59%), and 37% were married or cohabiting. Patients reported their race and ethnicity as white Hispanic (30%), black (33%), non-Hispanic white (24%), and multiethnic (13%). The major cause of ESRD was diabetes mellitus (48%), with 63% of patients having received dialysis for less than 1 year at enrollment. Only 10% of patients had a previous kidney transplant. The majority of patients (72%) identified themselves as Christian (22% were not affiliated with a religion, 3% were Muslim, and 3% identified as other).

Hemodialysis clinic networks

Patients and their interactions are represented in Figure 1. The network had two components: socially isolated patients (n = 14) who were not observed interacting with other patients and patients who were connected to other patients (n = 32). The connected component of the patient network can be further subdivided into patients (n = 24) treated on shifts of the MWF schedule and patients (n = 8) treated on the TTS shift. There were fewer TTS patients because there was only an MWF schedule when the clinic first opened. As the number of patients increased, the TTS schedule was added to meet the demand. One patient (a transplant-ineligible male) moved from the MWF shift to the TTS shift, linking the two subcomponents. There was no association between MWF and TTS assignment and network participation. The median seating distance between interacting patients was 3.4 seats with an IQR of 2.4–5.

Network participation

Thirty-two (70%) patients were observed interacting with each other in the hemodialysis clinic, forming the connected component of the social network (Table 1, Figure 1). Fifty-nine percent of patients reported discussing health information, and 44% reported discussing kidney transplantation with other patients (Table 2, Figure 1), usually (47%) within 3 months of entering the clinic. More networked patients discussed their health with clinic staff (75% vs. 14%, $p < 0.001$) and their nephrologist (91% vs. 64%, $p = 0.04$) compared with socially isolated patients.

The only demographic factor associated with network participation was sex; 81.5% of men participated in the network compared with 53% of women ($p = 0.04$; Table 1, Figure 1). Whereas a greater proportion of women were socially isolated, among network participants, only 45% of men discussed their health with other patients compared with 90% of women ($p = 0.02$, Table 2, Figure 1).

Attitudes toward transplantation, completion of steps to transplantation, and social networks

All patients participating in the social network (i.e. connected patients) wanted a kidney transplant compared with 71% of socially isolated patients ($p = 0.006$, Table 2). More of the network patients had asked for a living kidney donation than socially isolated patients (66% vs. 21%, $p = 0.01$, Table 2). Among the 37 patients eligible for transplant on enrollment, there were no differences in steps toward transplantation comparing patients who participated in the network (median 2, IQR 2–4.25) and their isolated counterparts (median 2, IQR 2–5.5; $p = 0.66$). In contrast, at the end of the study period, connected patients completed a median of 2 steps toward transplantation compared with a median of 0 for socially isolated patients ($p = 0.003$). Moreover, at the study's end, connected patients' median step was 5.5 in their workup, whereas socially isolated patients only progressed to a median step of 3. Seven patients (25%, four women and three men) participating in the social network received a kidney transplant compared with none of the socially isolated patients ($p = 0.16$).

We next examined steps completed toward transplantation for the 21 network participants (75% of transplant-eligible patients) at step 2 (interest) in the workup (Table 3, Figure 1: represented as squares). For the univariate linear regression analysis of survey, demographic, and network variables, the clustering coefficient (proportion of patients' alters interconnected) was significantly associated with completed steps (adjusted $R^2 = 0.19$, $\beta = 2.23$, 95% confidence interval [CI] 0.16–4.29; $p = 0.03$) (Table 3, Figure 1). In other words, if everyone in a patient's first-degree network was connected (clustering coefficient = 1.00), the patient would complete 2.23 more steps toward transplantation than if no one in their network was connected (clustering coefficient = 0.00). The patient's centrality in the network was not associated with step completion.

The most parsimonious multiple linear regression model based on survey and network variables included two predictors of completing steps toward transplantation: the mean completion of workup by alters and self-reported Christian religion. This finding suggests that if everyone in the patient's direct network completed their workup, the patient would complete 2.84 more steps toward transplantation than in a network where the mean completion was 0 ($\beta = 2.84$, 95% CI 0.11–5.57, $p = 0.04$). If the mean completion was 50%, patients would complete 1.42 more steps than in a network where the mean completion was 0.

The influence of these small highly interconnected subnetworks is evident in Figure 1. For example, on the TTS morning and afternoon shifts, three of the five participants underwent transplantation. Christian patients completed 1.58 more steps than did non-Christian patients ($\beta = 1.58$, 95% CI -0.11 to 3.27, $p = 0.06$). This model explained nearly 30% of the variance (adjusted $R^2 = 0.29$, $p = 0.025$). The residuals of the models were approximately normal, and the results were robust to the sensitivity analysis.

Discussion

This study provides novel and actionable information about the existence of social networks among in-center hemodialysis patients and the association of network characteristics with progress to kidney transplantation. Almost 70% of patients formed links with other patients, and many of these patients discussed health information and kidney transplantation. Although a larger percentage of transplant-eligible men participated in a hemodialysis clinic social network, a larger percentage of women discussed their health with other patients in their network. Potential transplant candidates in a network completed more steps toward transplantation than did patients outside of a network. Further, patients who interacted with each other completed a similar number of steps.

The exchange of health and transplant information among linked patients and the association of network participation with completed steps toward transplantation suggest that hemodialysis patient networks may be useful targets for practical and complementary interventions. For example, one intervention might (a) provide hemodialysis staff with accurate transplantation information (28) such as talking points or answers to frequently asked questions, (b) help them practice sharing this information in a conversational manner, and (c) encourage them to listen for and join patient conversations where they can reinforce or correct

Table 3: Associations among demographic, survey, and network variables, with the number of steps completed for patients in step 2 of the transplant process using linear regression with a randomization test[1]

	Univariate linear regression models predicting completed steps of patients starting at step 2 (n = 21)			Multivariable model predicting completed steps of patients starting at step 2 (n = 21) Adjusted R^2 = 0.29, p = 0.025	
Variable	Adj R^2	β [95% CI]	p value[1]	β [95% CI]	p value[1]
Age	−0.04	0.003 [−0.013 to 0.018]	0.67		
Ethnic minority (1 = yes, 0 = no)	−0.03	−0.72 [−2.84 to 1.40]	0.50		
Sex (1 = female, 0 = male)	0.07	1.21 [−0.37 to 2.79]	0.11		
Discuss health with other patients (1 = yes, 0 = no)	0.14	1.49 [−0.06 to 3.03]	0.054		
Christian religion (1 = Christian, 0 = other)	0.11	1.47 [−0.18 to 3.12]	0.07	1.58 [−0.11 to 3.27]	0.06
Self-reported health	0.13	−0.84 [−1.74 to 0.04]	0.06		
Mean completion of steps in network by members	0.14	2.66 [−0.07 to 5.41]	0.056	2.84 [0.11–5.57]	0.04
Number of links	−0.05	0.05 [−0.22 to 0.33]	0.71		
Eigenvector centrality	0.04	−4.09 [−10.10 to 1.89]	0.19		
Clustering coefficient	0.19	2.23 [0.16–4.29]	0.03		

[1] The randomization test assumes that the network variables are not independent and ues 10 000 permutations as a simulation to calculate the standard error.

any health and transplantation information being exchanged.

Hemodialysis clinic social networks may also be amenable to peer mentor and patient navigator interventions (40,45), as well as interventions that teach living donation communication skills (46). These interventions provide patients with factual transplant information and tools to help each other navigate the steps toward transplantation (40). While information and behaviors are more easily transferred from a peer than from a health care provider (40,47,48), the network's structure and function determine who should be targeted to spread information and behaviors (4,5). Weakly linked networks are characteristic of advice and expert networks, and the person in the center is the most influential. Strongly interlinked networks are characteristic of discussion and support networks, and influence is spread throughout (33–36). Whereas we found that patients in strongly interlinked networks completed more steps toward kidney transplantation, other studies found that patients in these networks were misinformed and failed to complete the steps (9). Moreover, patients can have a negative influence on other patients' attitudes toward transplantation (30). These seemingly contradictory results may suggest that strongly interlinked networks function as echo chambers that continually reinforce both positive and negative information and behaviors—making them good targets for interventions. Future research on the dissemination of behavioral transplant interventions should evaluate the effectiveness of targeting patients in a strongly interlinked network compared with patients in the center of weakly linked networks (4,5).

When nurses and physicians conduct the mandated transplant assessment (49), they can ask patients if they talk about health and transplantation with other patients and who they talk to. Once we determine how patients are linked, who is influential, and who can be influenced, we can study the effect of altering seating arrangements. Potentially, we can improve the completion of steps toward transplantation by seating patients who are interested in a kidney transplant among those who have completed their workup. Additional research is also needed to determine if linked patients who reinforce each other's negative behaviors should be separated and placed among patients who reinforce positive behaviors; a technique described in the education literature (50).

Consistent with other research (21,51), we found that women who participated in a network discussed their health with other patients more often than did men. They also completed more transplant steps than did women who did not participate. We recognize that most of our patients were men and, in general, people tend to interact with others of the same sex (52). This may explain why a smaller percentage of women participated in a hemodialysis clinic social network. Future research is needed to determine if our results are generalizable and if seating women and men together can facilitate the formation of mixed-gender networks that share health information.

We found no racial or ethnic differences in social network participation or completion of transplant steps. While Christian patients completed more steps toward transplantation, they composed 72% of all patients including those who did and did not participate in a network. With only 13 non-Christian patients in the study and limitations on the number of variables in the model, larger studies are needed to determine the meaning of this finding. Additionally, we asked only about religious affiliation and not religiosity. Future studies with larger samples of religiously diverse patients should ask about both religious affiliation and religiosity.

Our study has other limitations. The major limitation is that this was a single center study with a relatively small sample size (13). The number of patients was limited by the study design, which examined the *de novo* formation of social networks in a newly opened small hemodialysis clinic. While our sample size is small and there are more men than women, the ratio of men to women in this clinic is similar to other clinics in the Mid-Atlantic region (19). Another limitation is that although we observed and documented patient–patient interactions, we do not know the content of each interaction, nor do we have data on the occurrence and duration of every conversation, especially those outside of the clinic. Despite this, 95% of the patients who reported discussing health with other patients were observed interacting with other patients. The 40% of patients who did not report discussing their health with other patients but were observed participating in the social network may have been socializing.

It is also possible that linked patients completed more steps because they were extraverted. Extraversion is associated with better coping with illness (53) and better quality of life in kidney transplant patients (54). Although we did not directly measure introversion or extraversion, participation in strongly interlinked networks (measured by the clustering coefficient) is positively associated with both extraversion (55,56) and completing steps toward transplantation. In contrast, centrality (measured by eigenvector centrality) is only associated with extraversion (55,56) and is not associated with completing steps toward transplant. Additional research is needed to understand the association among extraversion, social network participation, and transplant steps.

While we collected data on many constructs associated with access to transplantation, we did not ask about health literacy, coping skills, or income (57,58). It is possible that the subnetworks of transplant-eligible patients who completed more steps toward transplantation formed social networks with like-minded patients who had similar coping skills and resources consistent with the concept of homophily (52). Future patient network studies should include measures of health literacy, coping skills, and other resources. Last, social isolation may indicate maladaptive coping (59) that is amenable to social network interventions (60,61).

In summary, our study demonstrated the existence of hemodialysis patient social networks and found that network participation was associated with an increase in the completion of steps toward transplantation. Larger studies are needed to explore the variation in hemodialysis social networks across other clinics and how hemodialysis-specific social networks can be targeted for interventions designed to enhance the likelihood of transplantation.

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Disclosure

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Supporting Information

Additional Supporting Information may be found in the online version of this article.

Data S1: Supplemental materials.