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Rural Health Networks: How Network Analysis Can Inform Patient Care and Organizational Collaboration in a Rural Breast Cancer Screening Network

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Abstract

Purpose—Rural health networks have the potential to improve health care quality and access. Despite this, the use of network analysis to study rural health networks is limited. The purpose of this study was to use network analysis to understand how a network of rural breast cancer care providers deliver services and to demonstrate the value of this methodology in this research area.

Methods—Leaders at 47 Federally Qualified Health Centers and Rural Health Clinics across 10 adjacent rural counties were asked where they refer patients for mammograms or breast biopsies. These clinics and the 22 referral providers that respondents named comprised the network. The network was analyzed graphically and statistically with exponential random graph modeling.

Findings—Most (96%, n=45) of the clinics and referral sites (95%, n=21) are connected to each other. Two clinics of the same type were 62% less likely to refer patients to the same providers as 2 clinics of different types (OR = 0.38, 95% CI=0.29–0.50). Clinics in the same county have approximately 8 times higher odds of referring patients to the same providers compared to clinics in different counties (OR = 7.80, CI=4.57–13.31).

Conclusions—This study found that geographic location of resources is an important factor in rural health care providers' referral decisions and demonstrated the usefulness of network analysis for understanding rural health networks. These results can be used to guide delivery of patient care and strengthen the network by building resources that take location into account.

Keywords

breast cancer; proximity; resources; rural location; rural networks

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To address rural-urban health disparities, researchers and policymakers have focused on how rural health networks can improve the infrastructure of rural health care systems and improve health care delivery. Rural health networks can range from an informal network of similar providers to a more formal, fully integrated network of providers who coordinate to deliver a full range of services.¹ They have the potential to not only improve care delivery but also improve care quality and reduce health care costs.² The Federal Office of Rural Health Policy currently funds several programs including ones to develop new integrative rural health networks and support mature networks,^{3,4} and researchers have also studied how to develop and foster rural health networks.^{1,5-7} However, despite the promise and focus on rural health networks, there has been little study of these networks using network analysis methodology.

Network analysis is a method for studying relationships and social processes by examining the links and interactions between people, organizations, or communities,⁸ thus making it an ideal method for studying rural health networks. For example, network analysis has been used to identify prominent leaders in a network⁹ and how organizations within a network work together to address specific public health concerns such as HIV/AIDS,¹⁰ tobacco control,¹¹ or cancer support.¹² Network analysis has also been used to inform interventions that strengthen an existing health network.¹³ The use of network analysis to specifically study rural health care, however, is limited. Recent work in cancer screening in rural Appalachia,^{14,15} farmer's mental health care in rural Australia,¹⁶ and chronic disease in rural Arizona¹⁷ demonstrates the promise of this methodology in this area but additional studies are needed to fully realize its potential.

Therefore, the purpose of this study was twofold: first, to use network analysis to understand how an informal network of rural breast cancer care providers coordinates and collaborates to deliver services to rural populations and second, to demonstrate the value of this methodology in this research area.

We chose breast cancer care providers as the target because of the well-documented disparity in breast cancer care between women in rural and urban areas. In rural areas inadequate access to health services (eg, low provider:patient ratios, long distances between providers, poor public transit) results in clinically significant delays across the cancer continuum.¹⁸⁻²² Delays in time to diagnosis (> 60 days) and treatment (> 90 days) after an abnormal mammogram increase the risk of poorer survival from breast cancer.^{23,24} One study found that for every hour increase in driving time to a primary care provider the odds of a breast cancer patient being diagnosed at a later stage increased by 27%, controlling for age, race and ethnicity.²⁵ In addition, women at higher risk for delays in transitions across the cancer continuum (ie, low income, uninsured, limited education) are disproportionately represented in rural areas.²⁶

Methods

Study Sample

The data for this study came from a larger study of patient navigation services for breast cancer care provided by Federally Qualified Health Centers (FQHC) and Rural Health

Clinics (RHC) (henceforth collectively called “clinics”) in 10 adjacent rural counties in Missouri. These counties were classified as rural based on the United States Census Bureau’s 2010 urban-rural classification system definition.²⁷ The average population of these counties was 29,707 with a range of 12,363 to 75,674.²⁸ Between 15% and 26% of residents in these counties are uninsured, and 16%–29% live below the federal poverty level.^{20,28} These specific 10 rural counties were chosen because their age-adjusted cancer death rates were the highest in the state and higher than the national average from 2005–2009.^{29,30} Organizational leaders at each of the 77 clinics in the 10 counties were asked to participate in the study.

Procedures

One leader from each participating clinic completed a survey related to the provision of breast cancer care and patient navigation services, and the network data for this study came from a single, free-recall question that asked, “Where does your clinic or health center refer patients for screening mammograms, diagnostic mammograms, and/or breast biopsies?” Respondents could list up to 5 organizations in response to this question (henceforth these organizations are collectively called “referral sites”). The results of this question were used to create the network for this study. Clinics and referral sites were represented as nodes in the network and clinics were “tied” to referral sites if they listed a particular referral site in the survey question.

To further understand the network, it was transformed from one where the clinics and the referral sites are connected to each other to one where only the clinics are represented as nodes and they are connected to each other if they share at least one referral site.^{31,32} This transformation allowed us to analyze what clinic characteristics were associated with sharing patients.

Data Analysis

The network was analyzed visually through graphical representation and statistically through structural analysis and exponential random graph modeling (ERGM). ERGM is an emerging statistical technique used to identify how the characteristics of the people or organizations in a network and larger social forces can explain or predict the observed patterns or ties in the observed network. ERGM allows social network data to be modeled in a way similar to least squares logistic regression but does not require observations to be independent.³³ Using ERGM, the outcome variable is dichotomous and represents the presence or absence of a tie between 2 nodes. In other words, these models predict the likelihood of any given pair of nodes being connected in a network.

To examine the likelihood of 2 clinics referring their patients to at least 1 of the same referral sites, we included 2 homophily terms in the model. A homophily term assesses whether ties are more or less likely between nodes who are similar to each other on some characteristic.³⁴ In our case, we entered homophily terms for type of clinic (eg, are FQHC-FQHC or RHC-RHC ties more likely than FQHC-RHC ties) and county location (eg, are ties between clinics in the same county more likely than ties between clinics in different counties). We

controlled for the total number of ties in the network by including the edges term, which serves the same purpose as the constant term in logistic regression.

Network analysis was conducted using the igraph v1.0.1 and statnet 2016.4 packages in R v. 3.2.2 (Vienna, Austria: The R Foundation). Network visualization was conducted using Pajek 64 4.01a (Ljubljana, Slovenia: Pajek) and NetDraw 2.148 (Lexington, KY: Analytic Technologies).

Results

Organizational leaders at 47 (10 FQHCs and 37 RHCs) of the 77 clinics agreed to participate (61% response rate) and at least 1 clinic from each of the 10 counties participated. The network consisted of 69 nodes: 47 clinics and 22 referral sites. Of the 22 referral sites, 11 (50%) were area hospitals. The other 11 included stand-alone radiology clinics, laboratories, and other types of providers. In Figure 1, the referral site nodes are sized according to their number of connections; thus, sites receiving more referrals are larger. There are 3 primary referral sites, as evident by the 3 largest nodes in the graph, with the remaining sites mostly on the periphery. A majority of clinics (79%, $n=37$) refer to 1 of these 3 sites. Most (96%, $n=45$) of the clinics and referral sites (95%, $n=21$) are connected to each other. There is 1 clinic that only makes referrals to 1 site, and no other clinic in the network also refers their patients to that site. This is represented as the “dyad” in Figure 1, where 2 nodes are connected to each other and nothing else. One clinic is isolated and makes no referrals. Unfortunately, we were unable to determine if this clinic truly does not refer its patients anywhere or if this survey item was purposefully or accidentally skipped. However, in line with rigorous and valid network analysis methods, we determined that the clinics who responded to the survey would be included in our network and therefore we chose to keep this clinic in the network even though it was not tied to a referral site.³⁵ On average, each referral site receives patient referrals from 4 clinics (mean=3.71, range=0–25). Figure 2 shows a histogram of the number of clinics that refer patients to each referral site.

In the transformed network, the nodes represent the 47 clinics and the nodes are connected if they refer their patients to at least 1 of the same sites. The nodes in Figure 3 have been sized based on the number of other nodes they are tied to. Forty-five clinics (96%, $n=47$) are connected in the transformed network, meaning each of these 45 clinics refer their patients to the same site as at least 1 other clinic. On average, each clinic refers patients to the same sites as 22 other clinics (mean=22.46, range=0–37). Two clinics are isolated in the network: the clinic that did not report referring its patients anywhere and the other that reported referring its patients to a site that no other clinic in the network refers to (the clinic from the dyad structure mentioned above in Figure 1). Overall, this indicates that the network is highly dense, with most clinics sending their patients to the same places as most other clinics.

The results of the ERGM are presented in Table 1. In this model we assessed the likelihood of 2 clinics being connected based on whether they were the same or a different type of clinic (meaning an FQHC or RHC) and whether the clinics were in the same or different counties.

Both covariates were significant predictors of tie likelihood. Two clinics of the same type were 62% less likely to refer patients to the same providers as 2 clinics of different types (OR = 0.38, 95% CI=0.29–0.50). Clinics in the same county have approximately 8 times higher odds of referring patients to the same providers as clinics in different counties (OR = 7.80, CI=4.57–13.31).

Discussion

This analysis of a rural breast cancer care provider network revealed that most breast cancer care providers are connected to each other in a rural area, though some clinics were isolated. We found that clinics in the same county were significantly more likely to refer patients to the same providers compared to clinics in different counties. We also found that clinics of the same type were significantly less likely to refer patients to the same providers compared to clinics of different types. Because FQHCs and RHCs are administered differently by the federal government, it seemed plausible that there may be top-down guidance on where a specific type of clinic should refer their patients. However, our results suggest that geographic location of resources is the driving factor in where clinics refer their patients and there is not some sort of characteristic unique to FQHCs or RHCs that drives their referral patterns.

The importance of geographic location revealed through ERGM can be seen in Figure 3, where clinics are colored based on their county location (color version available online only). One can see that many colors group together, which is consistent with the ERGM results that showed clinics in the same county are more likely to share referral sites. However, one can also see that for some counties this pattern does not appear. Clinics shaded light blue do not appear to group together, which suggests that for clinics in this county where they refer patients may not be driven by geographic location. One possible explanation may be that this county is centrally located in the region and patients of clinics in these counties have more resources in closer proximity. This deviation from the pattern warrants further investigation in the future.

These results have important implications. First, given the array of referral sites (hospitals, radiology clinics, etc.), the results of this study could be used to guide the dissemination of interventions that are applicable to all types of breast cancer care providers such as new screening or diagnostic guidelines or information about new Medicaid or Medicare procedure codes. In using our results to guide these dissemination efforts, one may assess the network visualization (Figure 1) and decide that the 3 referral sites where a majority of clinics refer their patients are the appropriate targets for an intervention. One may think that because a majority of clinics are connected to 1 of these 3 sites, this is the most effective strategy for disseminating the intervention through the network. And while this strategy will reach the majority of clinics, because our results indicate that county location is a significant factor in the network, it would be most efficient if efforts to disseminate an intervention throughout the network targeted 1 referral site in each county rather than the 3 main referral sites alone. This would make it more likely that the intervention reaches all clinics, including those on the network periphery. This is an important consideration because these clinics may serve the most rural patients who are even more affected by the rural-urban disparity.³⁶

Second, clinic leaders and policymakers could use these results to strategically develop a stronger network through resource and capacity building.^{9,13,17,37} For example, the identification of the isolated clinics and referral sites represents an opportunity for engagement and to build a stronger connection with those sites. Furthermore, understanding that geographic location is an important factor in how providers deliver care is important when planning resource and capacity allocation and building. If these efforts take into account providers' preference for local resources then the successful implementation and utilization of those resources may be more likely.

Limitations

The results of this study must be taken in the context of a few limitations. First, the generalizability of network analysis results is limited. Unlike traditional survey research where obtaining a random sample bolsters generalizability, the goal of network analysis is to obtain data on the entire network and not just a sample. Second, this study is also limited by the underrepresentation of RHCs in the sample. All FQHCs in the study population were included in the sample but only 55% of RHCs participated. Additionally, data on the participating clinics were obtained from a single leader from each clinic. There is the possibility that these results would have been different had additional or alternative leaders been surveyed. Third, it is possible that clinics would refer patients differently based on whether they needed a diagnostic mammogram or a biopsy, and we combined the 2 procedures in our survey question. There is the possibility that 2 different networks—one for biopsy referrals and 1 for mammogram referrals—could exist. Lastly, these data were collected from health care providers only. Therefore, patients' preferences in the referral decision are not captured and we acknowledge this is an important factor. Additionally, we recognize that patients may choose to go places other than where the clinics refer them, and these providers may not be captured in the network.

Conclusions

As health care in general moves towards a more network-oriented model with concepts such as the medical neighborhood,³⁸ system methods including network analysis will be key to studying and improving health care. Rural health networks have the potential to improve the quality of and access to rural health care and improve the rural-urban health disparity. Network analysis is an important method for studying rural health networks and can lead to unique insights that can be used to inform patient care delivery as well as organizational capacity and resource development. This study added to a growing body of literature demonstrating the feasibility and usefulness of network analysis for understanding rural health networks. This study also found that geographic location of resources is an important factor in rural health care providers' referral decisions. These results can be used to guide the delivery of patient care by understanding which providers are currently disconnected from the network and guide future efforts to strengthen the network by engaging these isolated providers and building resources and capacity that take geographic location into account.

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Figure 1.
Network of Referral Patterns of a Rural Breast Cancer Care Network

Figure 2.
Number of Clinics That Refer Patients to Each Referral Site

Figure 3.
Rural Breast Cancer Care Clinics Sharing of Common Referral Sites

Table 1

Predictors of 2 Clinics Sending Patients to the Same Referral Sites

	OR (95% CI)
Edges (constant)	1.56 (1.25–1.94)
Same Type of Clinic	0.38 (0.29–0.50)
Same County Location	7.80 (4.57–13.31)