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Research collaboration in the discovery, development, and delivery networks of a statewide cancer coalition

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Abstract

This study examines and evaluates collaborative network involvement among 18 organizations within the Arizona Cancer Coalition. All were involved in one or more of three types of research activity: discovery, development, and delivery, consistent with the 3D continuum developed by the National Cancer Institute. Data were collected in 2007 using surveys of key informants in each organization. Using network analysis methods, we examined the structure of each type of network as well as the relationship between network position and the importance of cancer research to each organization's mission. Findings indicated that while both the discovery and delivery networks were comparably densely connected, their centrality structures were quite different. In contrast, the structures of both these networks were similar to the development network. Centrality in the discovery and development networks was positively related to the importance of cancer research to the organization, but not in the delivery network. Implications of the findings for future research, policy, and planning are discussed.

Keywords

Organizational networks; Network analysis; Health

Coordination and collaboration have frequently been discussed as critical for enhancing the effectiveness of health and human service systems (Alter & Hage, 1993; Banaszak-Holl, Allen, Mor, & Schott, 1998; Bazzoli, Casey, Alexander et al., 2003; NCI, 2007; Provan & Milward, 1995) and for building community capacity in public health and medical communities (Chaskin et al., 2001; Leischow et al., 2008; Valente et al., 2008). The core argument is that despite potential problems and challenges (see Huxham & Vangen, 2005, for a discussion), by collaborating, organizations that provide a diverse range of services and skills can leverage scarce resources and share knowledge, thereby achieving better outcomes (e.g., more innovation and better coordination of services) than by operating autonomously (Agranoff, 2007; Lasker, Weiss, & Miller, 2001). This is the advantage of working as a system, which has become an important way of thinking about addressing critical health needs, including cancer control (Leischow & Milstein, 2006; Leischow et al., 2008).

While there has been a considerable amount of study over the past 20 years or so devoted to collaboration between organizations, until recently, much of the research in a health context was descriptive and non-quantitative. Many quantitative studies in other fields have also relied on ego-centric data, which are valid for examining dyadic ties, like partnerships, but not for examining what has been referred to as a “whole network” (Provan, Fish & Sydow, 2007). Increasingly, however, health systems researchers have begun to utilize the methods of social network analysis, which draws on relational data collected from the organizations that comprise a network (Luke & Harris, 2007; Valente et al., 2008; Varda et al., 2008).

While research on health services networks has grown considerably, we know very little about how organizations collaborate to facilitate the conduct of health research. This is somewhat surprising given the increased recent attention paid by NIH and other groups to translational research. Translational research has been defined by the NCI’s Translational Research Working Group (TRWG) as “research that transforms scientific discoveries arising in the lab, clinic, or population into new clinical tools and applications that reduce cancer incidence, morbidity, and mortality” (US Department of Health and Human Services, 2007, p. 1). The 2007 TRWG translational research report proposes that in order to meet the most pressing challenges for translational research there is a need to “improve coordination and collaboration and instill a culture of active, goal-oriented management for both individual projects and the enterprise as a whole.” Consistent with this challenge, two of the four platforms in the 2005 National Cancer Institute action plan, which focused specifically on cancer research, emphasized the need to “integrate infrastructures and collaborations through Cancer Centers, networks, and consortia to address large problems in human cancer” and “promote networks, partnerships, and coalitions to translate results of research into clinical practice and public health benefits.”

Outside the domain of cancer research, collaborating across organizations to share knowledge has been an important theme in the literature on organizations, especially in the area of biotechnology (cf. Powell et al., 2005). The idea is that the problem being addressed is so complex and involves such significant resources, that working independently is not a viable option. In addition, by sharing ideas, organizations and the scientists working in these organizations can build knowledge more rapidly and more effectively, thus improving both the quality of the research outcome and the time it takes to move from discovery to actual use by patients or other end users.

The study presented here was designed to build on these ideas, specifically examining collaboration in the cancer research network of a single state. In particular, our research is designed to study and evaluate the extent to which this collaboration occurs within or across three basic dimensions of research activity: discovery, development, and delivery. By examining these issues, we hope to develop a deeper understanding of the process by which disease-specific research findings might move from the “bench” to the “bedside” (Leischow et al., 2008). To accomplish our aims, we address three specific research questions. First, what is the structure of network relations among organizations involved in cancer research within a defined geographical area? Second, do the overall structure of network relations and the centrality of organizations in the network differ significantly when research activities are differentiated by discovery, development, and delivery? Third, to what extent is position in the research network related to the importance of the task; in this case, cancer research, for the organization as a whole? We discuss the implications of our findings not only for theory and future research, but also, for evaluating and planning such systems.

1. Research methods

1.1. Data collection

In 2003, the Arizona Department of Health Services (ADHS) received its first grant from the Centers for Disease Control and Prevention to establish a comprehensive cancer control program, including a statewide cancer coalition (Arizona Department of Health Services, 2005). A major theme of the Coalition was the need for a more integrated and coordinated approach to cancer research throughout the state. By 2006, the Coalition was in place and consisted of academic institutions, hospitals, the state health department, research institutes, and non-profit organizations, all of which were involved in some way in conducting cancer research. The Coalition's research committee was interested in determining if hoped-for collaboration across the full range of research organizations was actually occurring.

Data were collected in spring and summer 2007, with follow-up for missing information extending into 2008. Initially utilizing a 'nominalist' approach (Knoke & Kuklinski, 1982) to specify the boundaries of the network, we selected all organizations represented on the Arizona Cancer Coalition's research committee. Committee members assisted in reviewing and adding to the list of organizations, including all hospitals that submitted data on at least 40 cases to the health department's statewide cancer registry. Then, in keeping with the 'realist' approach (Wasserman & Faust, 2007, p. 31) for specifying network boundaries, we asked a small working group of research committee members to refine the listing and ultimately identified 34 organizations. Each of these were contacted to describe the purpose of the study, obtain support for participation, and determine the single person or persons in each organization who was most knowledgeable about their organization's cancer research activities. In most cases, this was the administrative or medical director of the organization's cancer services or the director of research activities.

Telephone calls were made to each of these contact persons to confirm his/her suitability to receive a survey. A cover letter and the network survey were then mailed to each of these individuals or to another contact person we were referred to who would be more knowledgeable. Follow-up letters and phone calls were made to answer questions and increase the response rate. Several organizations indicated they were not involved in cancer research even though they provided cancer care. Several of the hospital facilities identified were part of multi-hospital systems and we subsequently decided one system-level response would be most appropriate. Using this process of elimination, we reduced the referent population to 21 organizations.

Because of the importance of a high response rate for network analysis, substantial effort was focused on collecting data from every organization on the final list. We were successful in collecting complete information from 18 entities, for a response rate of 86 percent. The survey instrument design and methods used were based on previous network research by the author and colleagues published over the past 15 years. Besides the main network question, additional questions were asked about each organization.

For the network analysis, we collected data on the three broad types of relationships applicable to cancer research, as identified by NCI in 2005; specifically, those related to discovery (basic scientific research, tissue sharing, etc.), development (synthesis of new knowledge, developing new treatments, drugs, or prevention programs, etc.), and delivery (research on delivery of treatment to patients, prevention and early detection, etc.). Together, these three dimensions are thought to facilitate efforts toward translational research in health (US Department of Health and Human Services, 2007). The key informant respondent from each organization surveyed was asked to review the list of other Arizona cancer research organizations generated through the procedures described above. Each respondent was asked

to indicate on the survey (with a check mark) with which of these organizations their own organization had “regular ... collaborative involvement ... over the past 6 months” regarding each broad type of research (discovery, development, or delivery). Respondents could indicate involvement regarding one, two, or all three types of links for each organization listed.

1.2. Network analysis

The raw data were entered into Excel spreadsheets. The network/relationship data for the 18 organizations were coded as three binary matrices, one for each type of 3D link, depending on whether a link was reported (=1) or not (=0). These matrices were then copied into UCINET6 (Borgatti, Everett, & Freeman, 2002), a widely used software for statistical analysis of social networks.

We ran the analysis two ways, first looking at “unconfirmed” network ties, and then at confirmed ties. Unconfirmed ties are those where a respondent indicates that their organization is linked to another, but the other organization does not also identify that a relationship exists. Confirmed network ties are those where a linkage is identified by both partners. For the final analysis reported here we relied solely on confirmed ties. This is the most conservative approach and greatly enhances the reliability of network ties when little or no secondary data exist. Moreover, we utilized a strict form of confirmation in which each specific type of research tie had to be separately confirmed (i.e., discovery to discovery, development to development, etc.). A final matrix was also developed that included confirmation of any of the three types of research ties. This consolidated “any link” network provides a broader overview of the cancer research network in Arizona and helps overcome any problems of interpretation respondents may have had concerning what type of cancer research activity best defines the nature of their relationships with others.

Two global network-level statistics were computed for each network: centralization and density. Centralization shows the spatial distribution of ties in the network; essentially, the extent to which network activity is either clustered around one or few organizations or is more widely dispersed. The value of network centralization ranges from 0 to 1. Network density shows the overall connectedness of the network and is reported as a proportion (ranges from 0 to 1). The higher the score, the more connected the network (Wasserman & Faust, 2007, pp. 180–182).

For each of the four types of networks (discovery, development, delivery, and the consolidated *any link* networks) we produced network plots using the Netdraw procedure in UCINET, which is the way the data are displayed in the figures below. These plots address our first research question, describing graphically what these networks look like and demonstrating how they are similar or different. The individual nodes on the network plots are also coded by color and shape to distinguish the self-reported importance of cancer research activity to the overall mission of that organization, providing visual evidence for our third research question. In addition, to address more fully our second research question, we ran correlations to examine the extent to which organization-level indicators of structural position (using degree centrality) in one type of network were related to structural position in another. Because our network was relatively small ($n = 18$), there were few degrees of freedom, and thus, we did not run any multivariate procedures. We used degree centrality rather than betweenness centrality (Freeman, 1979) in our analysis in part because the former is easier to understand and interpret (simply a count of the number of links maintained by each organization), and in part because betweenness scores for all but two to five organizations (depending on type of network) were zero, providing a highly skewed distribution of scores, with little variance. In addition, degree centrality is more appropriate here since it captures the direct connection/involvement each organization has with others,

which is the purpose of our study, as opposed to betweenness centrality, which focuses on an organization's gatekeeping role in the network.

2. Results

The organizations studied devoted an average of 34 percent of their cancer-related budgets to research. Of that money, 31 percent of their research activities were related to discovery, 17 percent to development, and 52 percent to delivery. Consistent with these findings, and based on the data from the main network question in the survey, the network analysis indicated that the densest network was for delivery (.124), followed closely by discovery (.118), and then development (.065). These scores are substantially lower than the unconfirmed scores (.212, .203, and .163) for the same network type, although such differences are not unusual in network research of this type (Provan et al., 2003). The discrepancy in scores does demonstrate some uncertainty by respondents about the exact nature of their research ties, especially for development, where the discrepancy between unconfirmed and confirmed scores was greatest. However, both sets of scores reflect the same pattern of relationships, with delivery and discovery ties being more extensive than those based on development. Unlike discovery, which focuses on basic scientific research like the properties of cancer cells, or delivery, which focuses on how the actual diagnosis of and care to cancer patients might be improved, development is more difficult to clearly distinguish, often involving the synthesis of knowledge gained at the discovery phase so that basic research can be implemented at the delivery phase. The three networks were also moderately centralized, with similar centralization scores ranging from .429 for development, to .436 for discovery, to .491 for delivery.

The relationships uncovered in the discovery network are displayed in Fig. 1. In this network, the core actors were also those organizations most committed to cancer research as part of their fundamental mission. The only exception to this was Phoenix Children's Hospital (PCH—research reported as “highly essential to their mission”), which is an isolate regarding discovery research (isolates shown in upper left of each figure). Not surprisingly, the Arizona Cancer Center (AzCC) is highly central in the discovery network with eight confirmed ties (i.e., its degree centrality), with research reported as “highly essential.” However, the Translational Genomics Research Institute (TGen) had a total of 9 discovery research ties to other organizations (research reported as “highly essential”) in the state's cancer control research network, and most of these organizations were also connected to the Cancer Center. Thus, for cancer research related to discovery, the state's network had two, rather than only one central source of knowledge and expertise. In addition, these central organizations collaborated with each other, resulting in the strong likelihood that critical ideas and information would be shared across the network. Six of the 18 organizations studied actually had no collaborative discovery ties to the other 12, although four of these reported that cancer control research of any type was not central to the overall mission of their organization.

For cancer research related to development, the network was not very dense, with few relationships, nearly all of which were links to the Arizona Cancer Center. This can be seen visually in Fig. 2, which displays a classic “hub and spoke” pattern, with many isolates. The Cancer Center was clearly not only the most central actor in the system regarding development research, but it was also the primary broker, or intermediary, in relations between nearly all the other organizations that are involved in development research. Finally, it is apparent from the figure that with the exception of the Arizona Department of Health Services (ADHS, blue triangle = research “not very essential”), the organizations that were involved in the development network tended to be those that identified cancer research

as being at least moderately essential to their organization's mission (red/squares or green/diamonds).

When focusing on cancer delivery research (Fig. 3), the overall pattern of relationships was not too different from the findings for the development network. Although there were nearly twice as many links compared to the development network and only four isolates, the Cancer Center was still the most central actor. In addition, the Cancer Center alone continued to maintain the key broker role, acting as an intermediary in cancer delivery research relations between organizations depicted at the bottom half of the network (which were themselves reasonably well-connected) and those at the top half, which were not well-connected to each other. It is also interesting to note that in this delivery network, with the exception of the Cancer Center, organizations that identified cancer research as playing an essential role in their mission (TGEN, Mayo Scottsdale, etc.—red squares) tended not to be the most central actors in the delivery network. Four of the low research commitment organizations were involved in this network (blue triangles) and two of them (ADHS & PIMC) had at least four ties to other organizations regarding cancer delivery research.

The delivery network was very similar to the discovery network regarding density. However, as noted above and as discussed below in greater detail, the structures of these two networks were quite different. Specifically, the core actors in the discovery network were also the organizations that were most committed to cancer research as part of their fundamental mission, while this was generally not the case in the delivery network, with some exceptions. In addition, the dual broker role displayed in the discovery network was not duplicated in either the development or delivery networks.

The final plot shows the state's cancer control research network when the 3D distinction is loosened (Fig. 4). Instead of focusing separately on each type of research tie, the findings from the previous three plots were combined so that a link was counted if any of the three research dimensions were reported by any pair of organizations. For instance, if organization A reported having a discovery link with organization B, but B reported having only a development link with A, then for this analysis, we counted the link as confirmed and it appears in Fig. 4.

Not surprisingly, this 'any link' network was denser than any of the three component networks (.242). It was also quite centralized (.678). As with the more narrowly defined networks, once again the Cancer Center was the most central actor. But other organizations, especially TGen, had considerable involvement in the cancer control research network. The fact that this plot is so much denser than the other three networks suggests that the organizations across the state do interact with each other, both directly and indirectly through others, and that the distinction between discovery, development, and delivery in cancer research may be clear in theory but rather blurred in actual practice. The plot also shows that there is clear evidence of a network core and a network periphery. Ten of the 18 organizations, the network core, collaborated with at least three other organizations regarding their cancer research activity (either discovery, development, or delivery), while the other eight organizations had two or fewer research related connections (the periphery members). One of these organizations was an isolate and had no confirmed ties at all.

To examine further both how each of the three types of research networks are related and the extent to which organizational centrality in the networks is related to the organization's research focus (research questions two and three), we ran a correlation analysis. The results of that analysis are reported in Table 1. The findings offer evidence about network structure that is somewhat different from what was revealed through examining the network plots. First, organizational centrality in the development network is highly and positively

correlated with both centrality in the discovery ($r = .71, p = .001$) and the delivery networks ($r = .77, p = .001$). In contrast, the relationship between centrality in the discovery and delivery network is quite weak ($r = .33$, not significant). These findings are consistent with the conceptualization of the 3D formulation that discovery and delivery are at opposite ends of the research continuum, and thus, the central actors in each network are less likely to overlap. Development research, in contrast, provides something of a bridge between the other two, allowing some of the same organizations to be central in more than one type of research network. Second, the table shows that the relationship between network structural position, or degree centrality, and the importance of cancer research to an organization's mission, is strong and positive, but only for the discovery ($r = .61, p = .01$) and development ($r = .51, p = .05$) networks. In contrast, the importance of cancer research to an organization's mission had little impact on its structural position in the delivery network ($r = .20$, not significant), which is consistent with the fact that many of the organizations with a strong delivery focus, like the state health department and the hospitals, were not research entities and were engaged in little research.

The pattern of correlation results for the centrality in the three networks was confirmed using QAP (Quadratic Assignment Procedure) correlation analysis, available through UCINET. QAP enables a comparison of relationships in one network with those of another network having the same actors, by comparing the observed matching rate between two different types of relationships to the average of a large number of trials in which the actors in the network are randomly matched (Hanneman & Riddle, 2005). A correlation that is statistically significant would indicate that ties between actors in one network are also likely to occur in another network. This is exactly what we found with the relationship between the discovery and development networks ($r = .40, p = .05$) and between the delivery and development networks ($r = .46, p = .01$). As with the correlations for centrality, however, the relationship between discovery and delivery networks was weak ($r = .17$, not significant).

3. Discussion and conclusions

Overall, and in response to our research questions, the findings reported here demonstrate several things. First, it is clear from the 'any link' analysis that cancer research relationships within the state are occurring. While the 'any link' density score is not especially high (.242), these types of collaborative relationships are difficult to establish and maintain, so the finding that nearly one-fourth of all possible ties among organizations were already in place early in the network's evolution is a positive sign. The Centers for Disease Control provided funds to state public health agencies to create a cancer plan and establish state networks of collaborating organizations. Through use of network analytical methods, we have demonstrated that at least with respect to cancer research, the state of Arizona has made progress in achieving this goal. Because the network analysis was conducted after the creation of a state cancer control plan and after the creation of the Cancer Coalition, we cannot, however, infer any causal relationship between Coalition efforts to encourage collaboration and our findings that collaboration actually did occur.

Second, we were able to demonstrate that at least for this single case study conducted early in the evolution of the Coalition, the structure of the individual research networks depended on the type of research collaboration being considered; discovery, development, or delivery. The findings provided evidence that organizations within a health research system do not simply connect in a general way, but rather, they interact and collaborate based on the specific focus of that research. This finding has implications for efforts to encourage organizations to work with one another, especially when research interests and outcomes are somewhat different. It also has implications for researchers who study networks, suggesting

the need to collect data in ways that adequately discriminate among types of possible involvement (cf. Bolland & Wilson, 1994).

Despite differences, we also found some similarities when comparing the three networks. First, both the discovery and delivery networks displayed similar levels of density, indicating that these networks, rather than the research development network, were the most active regarding interorganizational coordination and collaboration. Second, we found similar patterns of relationships and levels of organizational centrality between the development network and the other two research networks. In contrast, the discovery and delivery networks displayed relationship structures that were quite different from each other. While the Arizona Cancer Center maintained its central position in all three networks, there were differences in the centrality of the other research organizations, depending on which network was considered. Finally, we found that organizations whose commitment to cancer research was highest were most likely to maintain central positions in both the discovery and development networks. This was not, however, the case for the cancer research delivery network.

One key goal was to assess not just collaboration in general, but to explore to what extent the research collaboration was translational. Thus, we used the discovery, development and delivery framework to address the key components of the translational research process. This characterization has been useful in some respects, but not in others. For example, as an NCI-designated comprehensive cancer center, the Arizona Cancer Center should be strong in all three domains of translational research, which is what respondents reported. TGen is primarily a basic science organization, so our finding that their central role in the discovery network – but not in development and delivery – is logical. In contrast, although the Mayo Clinic is a comprehensive cancer center nationally, in Arizona, it is central only in the discovery network.

The Arizona Cancer Center has strong ties with many other organizations involved in discovery through delivery, so it is well positioned to fulfill its intended role within the state as an NCI-designated comprehensive cancer center. This is particularly noteworthy because it is not centered in the Phoenix area, the largest city in Arizona and where many of the other cancer research entities are located. Thus, the Cancer Center has been able to maintain a central network position despite proximity disadvantages (Stuart & Sorenson, 2003). Current efforts of the Cancer Center to expand significantly into the Phoenix area in conjunction with the new University of Arizona medical school should allow strengthening of its central position within the state regarding translational research. Future network analyses would be able to assess changes like this, over time.

An important conclusion of our work is that cancer or other health research may not be easily separable into the neat categories of discovery, development or delivery. While we found value in breaking research down into these categories, it may also be that the distinction was not always clear to respondents, based on their actual practices, even though each term was defined clearly on the survey. Our experiences led us to conclude that discovery and delivery appear to be adequate in distinguishing roles and characterizing which organizations are conducting translational research. However, based on the large discrepancy between raw and confirmed network scores, ‘development’ may have been more difficult to conceptualize, especially when responding to the nature of research ties with partner organizations. It is also reasonable to have found that the Cancer Center was highly central in all three networks, since the role of such a center in fostering translational research along the entire 3D continuum is central to its mission.

The finding that the delivery research network was relatively dense is also logical since many more organizations have active roles to play in research pertaining to cancer care, such as the role of the state health department in tracking and diagnosing cancer cases or various hospitals that are responsible for cancer care. Our finding that the delivery research network was the densest of the three is consistent with the mean amount of resources devoted to delivery (52 percent of total cancer budget in our sample) compared to discovery (31 percent) and development (17 percent).

Despite the valuable information gained from this study, there are limitations as well. First, ours was a case study of a research network in a single state. Thus, the findings must be viewed as suggestive and not necessarily generalizable to the cancer research networks in other states. In addition, the network was not large, precluding use of more sophisticated multivariate analyses. This is a general problem with network analysis since large networks of organizations are often not found, due primarily to the complexity of their management and governance. Second, because we collected network information from just one key informant from each organization (except in a few cases of exceptionally large organizations), it is possible that we missed some relationships that would have altered the results. This shortcoming was mitigated to some extent by focusing on analyses of confirmed relationships. In most networks like the one studied here, there is only very limited objective data available on relationship ties across organizations, and even when available, the data are seldom comparable. As a result, use of key informants and confirmation of ties is likely to be the best approach for collecting data on network relations, given limited resources. Third, we only included in the analysis those organizations that self-identified as being involved in cancer research, so it is possible that we missed some research organizations if they chose not to participate in the statewide cancer control coalition. Of course, our focus was specifically on the Arizona Cancer Coalition, so our findings and conclusions are limited to that group of organizations.

A final limitation is that we focused solely on cancer research, which does not speak to the nature of the cancer control network as a whole, especially in areas like advocacy or education. Future studies could also examine a broad range of research links, including joint publications, collaboration on grants, and so on, to better understand exactly how the research network operates. In addition, our findings may not be generalizable to other health research settings outside of cancer control. Research networks in other areas of health are no doubt struggling with the need to bridge the gap among organizations working on different components of the research process, from discovery to development to delivery. Our work is limited in this regard but it does offer some possible new directions for examining network-wide collaboration among health research organizations in other settings.

3.1. Lessons learned

As a first assessment of its type, the results are significant in several ways. First, the use of network analysis as a systems-level evaluation tool greatly facilitated an understanding of which organizations involved in a particular health issue; in this case, cancer control, were actually collaborating on research, as well as which ones were not. From a practical policy and planning perspective, this knowledge can be used to foster ties that do not currently exist to assure that collaboration is optimized statewide. Second, the results showed that while the state's cancer coalition has many strong research ties, only one organization, the Arizona Cancer Center, played a strong role as the hub for translational research, maintaining ties across all aspects of the 3D framework. As policy makers, health care system planners and organizers, and the public press for more translational research in all areas of medicine, organizations that are strong in the discovery to delivery 'chain' will be in the best position to play the strongest leadership roles in fostering improvements in prevention and care as a result of their dense connections within a defined region.

Despite some limitations, this analysis clearly demonstrates that national policy efforts to influence the dissemination and integration of research knowledge across organizations, at least at the state level, can and does occur. In our study, which focused only on efforts within a single state, cancer research efforts were generally well-connected, especially through what Provan & Kenis (2008) have recently referred to as governance of a network through a single “lead organization,” and include relationships spanning discovery, development, and delivery. Much more can and should be done to understand and evaluate this and other health research networks so that it will be possible to speed the process of translating research discoveries to patient delivery. This study demonstrated that ‘network centric’ cancer research activity can be empirically assessed and that the extent and composition of network interaction varies across organization type (including mission) and across dimensions of the 3D framework. Ideally, the results of our study can be used not only as the basis for future research, but also, as the basis for evaluation of statewide efforts to control cancer and other major diseases through the efforts of multiple organizations, thereby strengthening the likelihood that such systems will succeed.

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Key: Importance of Cancer Research to Organization's Mission

- = Highly Essential
- ◆ = Modestly Essential
- ▲ = Not Very Essential

Fig. 1. Arizona cancer research network—discovery network. Centralization = .436; density = .118. Key: importance of cancer research to organization's mission—(■): highly essential; (◆): modestly essential; (▲): not very essential.

Fig. 2. Arizona cancer research network—development network. Centralization = .429; density = .065. Key: importance of cancer research to organization's mission—(■): highly essential; (◆): modestly essential; (▲): not very essential.

Fig. 3. Arizona cancer research network—delivery network. Centralization = .491; density = .124. Key: importance of cancer research to organization's mission—(■): highly essential; (◆): modestly essential; (▲): not very essential.

Fig. 4. Arizona cancer research network—"Any Link" network. Centralization = .678; density = .242. Key: importance of cancer research to organization's mission—(■): highly essential; (◆): modestly essential; (▲): not very essential.

Table 1
Correlation matrix of measures of network centrality and research mission ($n = 18$).

	Mean	S.D.	1	2	3	4
1. Discovery	2.0	2.66				
2. Development	1.1	1.91	.71 (.001)			
3. Delivery	2.1	2.45	.33 (NS)	.77 (.001)		
4. All links	4.1	3.86	.83 (.001)	.77 (.001)	.73 (.001)	
5. Research mission ^a	2.0	0.84	.61 (.01)	.51 (.05)	.20 (NS)	.43 (.10)

Pearson correlation coefficients are reported. Significance level (p) reported in parentheses.

^a Organizations were coded as 1 (not very essential), 2 (modestly essential), or 3 (highly essential) based on self-reports from the survey.