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Measuring Social Network Structure of Clinical Teams Caring for Patients with Complex Conditions

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Abstract

Chronic, complex health conditions require teams that communicate effectively to be able to achieve best outcomes. In this study, we assessed the communication structure using social network analysis (SNA) for three distinct multidivisional teams caring for populations of children who have undergone liver transplantation, have been diagnosed with cerebral palsy or have been diagnosed with intestinal rehabilitation. In most cases, team members were geographically dispersed at the hospital campus, thereby requiring team members to depend on email for much of their communication. We used the Condor Social Network Analysis tool (Condor) to analyze the email communication patterns of team members. In our longitudinal analysis, we measured ties, betweenness centrality, contribution index, and density using social network metrics.

Distinct patterns and structures of communications emerge among the teams' leadership. In the Liver Transplant team and the Intestinal Rehabilitation team, the leaders communicate as a core group. On the other hand, in the Cerebral Palsy team, one of the four leaders assumes a very peripheral position mostly communicating with the partners outside the hospital. Furthermore, other people from outside the Cerebral Palsy team exhibit much higher betweenness centrality. The distinct patterns of communication flow lead us to ask if the Cerebral Palsy team may improve team function through better integration of the team leaders. Based on these initial observations, we think it is likely that SNA of communication patterns can increase the efficiency of team development and enhance team function in geographically dispersed health care teams thereby increasing their effectiveness.

Keywords: Social Network Analysis; COINS; Clinical Teams, Team Network Structure

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1. Introduction

Complex, chronic conditions have long been a challenge for providers and the health care delivery system. Best outcomes depend on decision support, effective delivery systems, information systems and active communications among the health care provider team members and patients (Wagner, 2001). The foundation of quality care depends on interactions of providers with diverse areas of content expertise.

While team communication has been studied in emergency and operating room settings, mostly with regard to safety, the effort has not been spread widely to interdisciplinary teams caring for populations of children with chronic and complex conditions (Makary et. al., 2006). One potential way to improve team communication is to use findings from the science of Social Network Analysis (SNA) and the study of human interactions. One method of SNA logs email interactions over time to allow patterns and trends to be observed and evaluated. Different patterns of communication emerge for different teams. Because the speed and modes of communication have expanded over the last two decades and their impact on the workplace is significant, SNA is a key framework to use when studying team communication.

2. Goal

We used SNA to assess three multidivisional health care teams' email communications at Cincinnati Children's Hospital Medical Center (CCHMC). We made the assumption that email communications are an accurate reflection of all the teams' communications. While the goal of this paper is to document and compare the team's communication structures, it also formed the foundation for future efforts (1) to determine if SNA reveals distinct communication patterns among health care teams, (2) to determine if those patterns relate to the stage of team development and function (See Table 1), and (3) to define interventions to improve their team function. Similar to other industries, we predict that such efforts will improve patient outcomes, patient satisfaction, research productivity, and program reputation. To do so, we defined and compared SNA metrics among the Liver Transplant, Cerebral Palsy and Intestinal Rehabilitation teams.

3. Theoretical Background

During the last decades, social and computer scientists have studied the effectiveness of collaboration in working environments, including some recent contributions to improve throughput of surgery patient flow process (Samarth and Gloor, 2009). The investigations have identified the importance of interactivity as the determinant of positive performance in teams where the supportive dimension of exchanges is balanced by the interactive one. Analogous to this, in the healthcare setting, teamwork and team function have come to the forefront as factors that influence patient safety and outcomes. With regard to caring for critically ill patients, "providing structure to physician and nurse communications is an effective method for improving shared understanding of [a] situation" (Sexton et al., 2006). Specifically, regarding communication in the operating room, teamwork was demonstrated to impact efficiency, quality of care, and patient safety. In fact, in 2005, communication breakdown was cited as the most common root cause of wrong-site operations, operative and post-operative events (Sexton et al., 2006).

A model of chronic care introduced by E. H. Wagner (2001) has been shown to be effective for patient populations with diverse conditions. The model suggests that best outcomes depend on productive interactions among patients and health care provider teams. Those interactions depend on commitment to self-management, decision support, a reliable clinical information system, an effective care delivery system, community support, and implicitly effective health team function and communication.

Other authors (Ancona and Bresman, 2007) have proposed key principles that represent a pattern for successful teams across different sectors: *extensive ties, exchangeable membership and expandable tiers*. Effective groups, defined by the authors as extended communities or X-teams, are able to build extensive ties and go beyond their boundaries, adapting their structure over time to enable useful outsiders to contribute on common projects. Exchangeable membership means inclusion in the community of people who come in and out and rotate leadership. The third principle of the extended community is expandable tiers, which means adopting a flexible structure with a core group that coordinates the community, a group of other members who carry out the activities, and others who drop in and out for short periods. Each member brings his or her special knowledge and capabilities, but also interpersonal relationships with the rest of the community as well as with external members (Wenger and Snyder, 2000). To measure the ability of a team to connect with important stakeholders, SNA provides useful tools and metrics to quantitatively assess the evolution of ties and the impact on team structure (Borgatti and Everett, 1999, Wasserman and Faust, 1994). As shown by recent research studies in the field of dynamic Social Network Analysis, it is possible to use SNA metrics to recognize effective teams and collaborative innovation networks (Gloor, 2006). Collaborative Innovation Networks (COINs) form from the interaction of like-minded, self-motivated individuals who share the same vision. An innovative idea is pushed forward by charismatic leaders, who assemble a group of highly motivated collaborators. These people join not for immediate reward, but because they share a common vision.

4. Study Methodology

We analyzed email communication patterns of the members from the Liver Transplant, Cerebral Palsy and Intestinal Rehabilitation teams at CCHMC. To parse emails and collect social network metrics, we used Condor, a software suite that can take email archives and translate them into data of the sender, recipient(s), and date/time of each message. With this data, Condor can generate sociograms, adjacency matrices, and interactive movies of communication flows. A sociogram is a graph that visually represents the inter-relationships within a group, where each node is an actor and each line represents an email communication between actors. The shorter the distance of the line between two actors, the higher their frequency of email communication.
The opportunity to participate in this project was presented to 11 health care teams at CCHMC who care for populations of children with chronic, complex conditions. Three teams volunteered to serve as subjects in this pilot study. Team members included physicians, nurses, ancillary health care professionals, administrators, administrative support staff, and research coordinators. We defined the team as those who spend at least 20% of their effort working on the condition team and observed the communications among all members in this group. The role of each actor was determined by his/her job description and designated as care delivery, research, outcomes measurement/quality improvement, strategic leadership, program and administrative support. The initial Condor analysis was performed using one team leader from each team. Snowball sampling was then used to identify 3-4 additional team members for which to obtain the initial sociograms. The study was considered to be exempt by the CCHMC Institutional Review Board.

4.1 Team Descriptions

Liver Transplant Team
The Liver Transplant team at CCHMC performs approximately 25 transplants per year and provides care to children who require liver transplantation in a radius of approximately 250 miles. Since 1986, more than 500 liver transplant operations have been performed at CCHMC. The team continues to provide long term follow-up care to this population. The program is considered to be in the top 5 with respect to volume and reputation in North America. The team is led by two hepatologists, a surgeon and the director of transplant services. The team includes additional transplant surgeons and hepatologists, pre-transplant and transplant nurse coordinators, social worker, research coordinators and applications/systems analyst. An extended team includes inpatient care nurses, financial analysts, contracting experts, and administrative support personnel. The team currently has funded research from NIH for six patient based studies.

Cerebral Palsy Team
The Cerebral Palsy team at CCHMC provides care and integrated therapy services for children and adolescents and assistive technology services for all ages. The team serves approximately 200 children per year, about 85% from the immediate Cincinnati area. This recently formed multidivisional team including members from the divisions of Physical Medicine and Rehabilitation (PM&R) and Occupational and Physical Therapy (OT/PT), as well as members from the Aaron W. Perlman Center. The leadership team is comprised of two physicians from PM&R, a clinical director from OT/PT, and the Senior Director of the Perlman Center. The larger team includes individuals in the following roles: nurses, physicians, physical therapists, occupational therapists (with special expertise in assistive technology), registered dietitian, and social workers. An extended team includes a business director,

administrative personnel, and a research coordinator. Overall the team is working to develop research protocols and participate in several multicenter networks.

Intestinal Rehabilitation Team

The Intestinal Rehabilitation team provides comprehensive care to all patients with or at risk for intestinal failure. Intestinal failure is defined as decreased intestinal function requiring chronic intravenous nutritional supplementation. The team provides care to patients from Ohio and surrounding states. The team previously included only members from the Division of Gastroenterology (GI) but has expanded to include members of the Divisions of Neonatology and Surgery, respectively. The larger team is comprised of surgeons, physicians, nurse practitioners, nurses, care managers, social work, a registered dietician, and an applications/systems analyst. Members of the extended team include a business director, research coordinators, administrative, and business personnel. The team has several research protocols and participates in national networks that maintain registries for this population.

4.2 Measures

We used social network metrics for our analyses (Table 1). The density of the network is reflected by the connectedness of the nodes. Other metrics such as betweenness centrality can be used both at the group level to understand macro level characteristics of the team, and at the individual level to understand relative positions to other colleagues, partners and collaborators. The betweenness of a node measures the extent to which a member can play the part of "gatekeeper" controlling access and the flow of information (Borgatti and Everett, 1999, Wasserman and Faust, 1994, Gloor, 2006). The SNA perspective suggests that the power of individual actors is not an individual attribute, but arises from their relations with others. In other words, the strength of the team's communications may come from the synergy of connections. Density and centralization are important complementary measures. Density describes the general level of cohesion in a sociogram, while centralization describes the extent to which this cohesion is organized around particular focal points which can be one node or a cluster of nodes. Another important structural property of social networks – defined structural hole - has been proposed by Burt (1992). The author defines structural holes as the weak connections between clusters of densely connected individuals. The role of brokers normally focus on establishing ties to other disconnected groups, exploiting the structural hole so that they can then bring together members of the two groups who would otherwise be more difficult to connect (Burt, 1992).

Metrics and Structural Indicators	**Description**	**Benefits**
Actor Betweenness Centrality	The number of times an actor connects pairs of other actors, who otherwise would not be able to connect with one another. It measures the extent to which a particular point lies "between" the various other points in the graph. It is also defined as the total number of shortest paths between every possible pair of nodes in a graph that pass through a given node.	Recognize gatekeepers and boundary spanners who fill structural holes.
Contribution Index (CI)	CI is +1, if an individual only sends email messages and does not receive any email message. CI is –1, if an individual only receives email messages, and never sends any email messages. CI is 0, if an individual sends and receives the same number of email messages.	Evaluate actors' interactivity level, or the level of active participation of an individual in the team.
Group Betweenness Centrality (GBC)	The GBC of the entire group is 1 for a perfect star structure, where one central person, the star, dominates the communication. The GBC is 0 in a totally democratic structure where all actors display an identical communication pattern. It is the total fraction of shortest paths between all pairs of vertices that pass through at least one vertex in the group.	Plotting the changes of GBC allows observers to distinguish different communication patterns over the lifetime of a social network. GBC can be used as a measure of the group's collaborative capabilities
Core/Periphery Structure	A network has a core/periphery structure if the network can be partitioned into two sets: a core whose members are densely tied to each other, and a periphery whose members have more ties to core members than to each other.	Recognize the extent to which a network revolves around a core group of nodes. Identify the presence of a dense, cohesive core and a sparse, unconnected periphery.

Density	The total number of relational ties divided by the total possible number of relational ties. It allows evaluation of the network's compactness and the presence of sub-groups.	Measuring the density of a network provides an index of the degree of connection in a network.
Structural Holes	Holes in the social structure of a network that can be filled by connecting one or more nodes to connect other additional nodes. The existence of a structural hole allows the third actor to act as a broker or intermediary.	Actors who have these connections can act as brokers between the clusters or groups.
Connectivity	A property of the network's shape and refers to how actors in one part of the network are connected to actors in another part of the network. It is calculated observing the number of nodes that would have to be removed in order for one actor to no longer be able to reach another. If there are many different pathways that connect two actors, they have high connectivity.	It is a useful measure to understand dependency and vulnerability of the network.

Table 1. Metrics and Indicators of Social Network Analysis used in this study (Borgatti and Everett, 1999; Wasserman and Faust, 1994; Gloor, 2006; Burt, 1992).

As stated by Gloor (2006): "*The lower the group betweenness centrality (GBC) and the higher the graph density at a particular time, the more people in the network are talking to each other in a democratic way on even terms*". Other types of communities can be identified looking at SNA group-level indicators, such as Collaborative Learning Networks (CLN) and Collaborative Interest Network (CIN). Members of a CLN share a common interest, knowledge and practice, and are motivated to join the communication network by the desire to learn from each other. Members of CIN have similar interests, but do not actually work together. Both CLN and CIN are characterized by lower density, but higher GBC than COINs. In COINs, external members are mainly connected to core members, but do not communicate among themselves. The core team of a COIN usually has high density, but low GBC.

4.2 Data Analysis

The results are based on the sociograms and on metrics from the analysis of seven months of emails exchanged within the three teams. First we looked at the internal degree of connectivity, identifying clusters, the most central actors, and the most active contributors. Dynamic maps of the social networks were plotted over time to look for changes in team communication as the teams developed. To have comparable results across the three teams, the time frame for the dynamic visualization has been standardized. Approximately seven months of data is included for each team beginning on January 1, 2010. Finally, we compared the results from the analysis of the three teams and observed how their communication patterns differ. The analysis included the following steps: 1) observing the actors within each team who spend 20% or more of their time/effort on that team; 2) observing the complete network of actors within each team who interact. In the complete network, actors are exchanging information not necessarily related to the goals of the team with people internal and external to CCHMC.

5. Results

5.1 Liver Transplant Team

Figure 1 illustrates the sociogram of the Liver Transplant team members dedicating ≥20% of their effort. The 26 actors are connected through 219 ties and can be recognized by the direct involvement in specific domains: care delivery, research, measurement, strategic leadership, and program support including administrative support and program management.

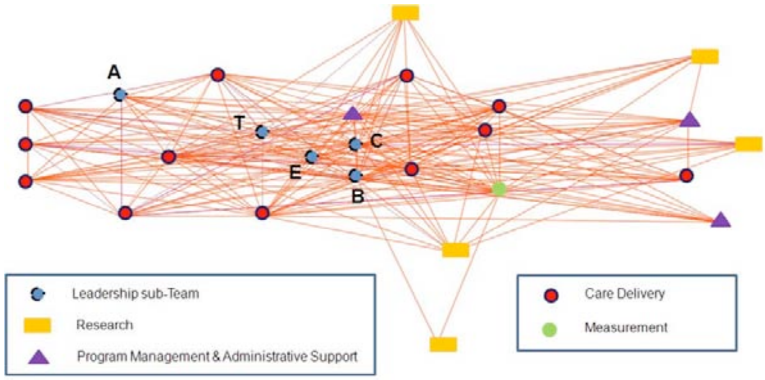

Figure 1. Sociogram of the Liver Transplant team

Members working to support the Liver Transplant team in the business, operational and administrative domains (triangles in Figure 1) are quite peripheral and are mainly receivers of communication with an average Contribution Index (CI) close to -1. (See Figure 2) While the most active communicators are the team leaders, who have the highest CI and the highest betweenness centrality. Members in the care delivery domain are well connected to each other and to other members, though they all have relatively low CI values, consistent with their role as knowledge experts (Gloor, 2006). This data seems to indicate that the Liver Transplant team is effectively collaborating as a COIN, where members usually take on roles of creators or gurus (CI=0), collaborators (CI>0 and high communication frequency), communicators (CI close to +1) and knowledge experts (CI close to -1). Gurus are members of the COIN with a leadership position: they are usually masters of sharing not only the work, but also the reward (Gloor, 2006). The leadership core group normally relies on the expertise of members from different units within the hosting organizations, which Peter Gloor calls knowledge experts.

Figure 2 also shows the CI of the individual team members. We found that the strategic leaders have an active role in the communication process, both as receivers and senders of emails. These strategic leaders play the typical role of collaborators by organizing and coordinating tasks, as well as gurus by providing the overall vision and guidance to the team.

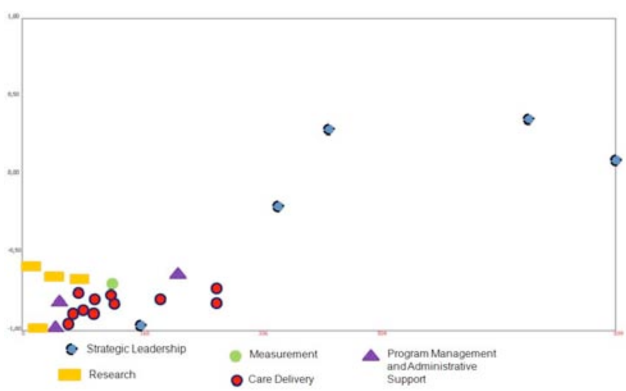

Figure 2. Contribution Index of the Liver Transplant team members (x-axis is contribution frequency)

We also looked at the whole network based on the email exchanged among the team members and actors outside the team, the latter including actors within and outside CCHMC. We did so to assess the team's ability to activate extensive and expandable ties with important institutional and external stakeholders. We found that the most peripheral actors, especially the five members of the research domain (rectangles in Figure 1) have extensive ties with internal members of CCHMC, and with members of other children's hospitals across the United States and Canada. The same pattern of creating strong external connections is visible if we consider the ties developed by the leaders across institutional boundaries. One of the strategic leaders (B in Figure 1), exchanged a total of 305 emails with external institutional actors (16% of the 1887 emails sent and received by B.). Most of the interactions involved members of other children's hospitals in New York, Texas, Illinois, Pennsylvania, Canada, but also other health-related organizations, such as: hospitals, doctors' offices and outpatient sites, long-term care facilities and health insurance services. The other leaders were also well connected to external actors, though in smaller percentages. Another leader (T in Figure 1), had also important connections to other hospitals, research centers and academic consortia across the United States (7% of the 2620 total interactions).

5.2 Cerebral Palsy Team

Figure 3 illustrates the sociogram of the Cerebral Palsy team. The first result that emerges from the visual map is the clear identification of three separate clusters built around three of the four program leaders. The three clusters are only connected through the fourth leader (VA in Figure 3), who is the second most central actor in terms of betweenness centrality (Cb=0.18), after the leader W (Cb = 0.19).

Each cluster, which represents one of the divisions/programs making up the Cerebral Palsy team, seems to interact as a separate, independent ecosystem: each cluster is composed of a leader, a tightly connected group of people working in the care delivery domain and other actors working in the program management domain. VA serves as a bridge across the clusters. To illustrate the potential drawback of the Cerebral Palsy team's network configuration, we removed VA who acts as information broker. By doing so, we measured the resilience of the network, that is its ability to respond and adapt to the addition or removal of connections (e.g. because of job rotation or merging of teams). The six actors who disappear from the team network were interacting both with VA and W. Without the information broker VA, the social network is now composed of 63 actors and 431 ties from the original 479 ties connecting 69 actors, with a decreasing core/periphery structure (from 0.23 to 0.22) and an increasing density (from 0.0097 to 0.1103). The change in the network structure is not dramatic (lost ties are only 10%), but it is still an indication of the prominence of one leader, VA, who is connected to important members such as the only actor working in the Research area (see rectangle in Figure 3/Left, who does not show up in Figure 2/Right).

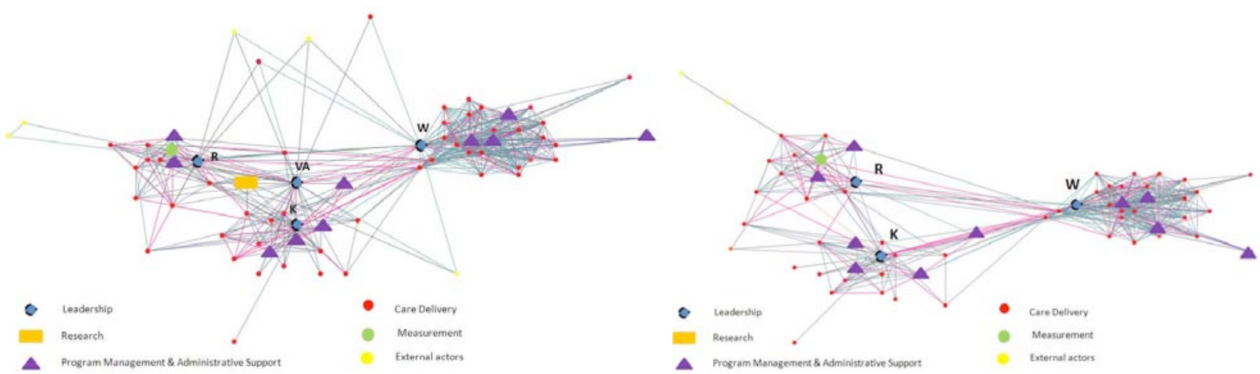

Figure 3. Sociogram of the Cerebral Palsy team (left: with VA, right without VA)

Another result is the scattered position of the leadership team within the Contribution Index Plot (see Figure 4). Two of the five formal leaders are low contributors, which means that they exchange a small number of emails (on average 200 each) and they mainly receive emails from others. With the exception of K and R, the other leaders do not play the strategic role of coordinators or gurus. Their CI is very low which indicates a more passive role in the communication process. On the other hand, the role of coordinator and expediter of communication seems to be played by a business manager (Business Manager triangle in Figure 4) showing high contribution frequency and balanced communication pattern.

Figure 4. Contribution Index of the Cerebral Palsy team (x-axis is contribution frequency)

When looking at the whole network represented by the connections between the Cerebral Palsy team members and the people working on other projects at CCHMC or external institutions (See Figure 5.), we found that RR - the fifth most central actor and a team leader - had extensive ties with external institutions, while the other team members were mainly internally focused. Recognizing and exploiting these external connections can be a source of new information and collaborations for the Cerebral Palsy team.

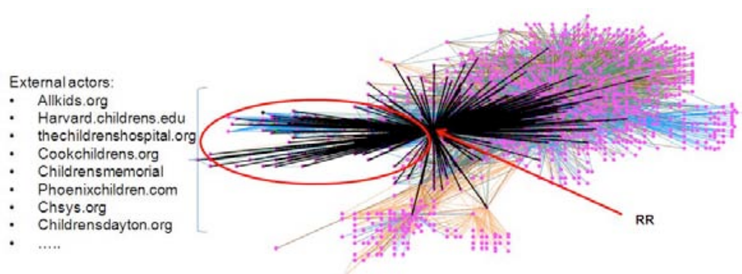

Figure 5. Sociogram of the whole network involving internal and external connections

5.3 Intestinal Rehabilitation Team

The topological structure of the Intestinal Rehabilitation team's communication network, as shown in Figure 6, is characterized by the central position of the program leaders. The program leaders interact mainly with members of the care delivery domain. The research team member is not completely integrated, as indicated by the low CI (-0.60) and by the number of communications over time (only 34 emails exchanged). This may be due to the fact that this member's effort is split between two teams, the Intestinal Rehabilitation and Liver Transplant teams. Analyzing the communication for this member, who plays the role of information broker, we noticed that this member is equally connected with the Intestinal Rehabilitation and Liver Transplant teams (29 ties with the Liver Transplant team versus 31 ties with the Intestinal Rehabilitation team.)

Figure 6. Sociogram of the Intestinal Rehabilitation team

The CI of the Intestinal Rehabilitation team members illustrates how active members are in terms of both number of emails exchanged (contribution frequency) and ratio of emails sent/ received (see Figure 7). The Liver Transplant team and the Intestinal Rehabilitation team members show a similar communication pattern, typical of a COIN. Two leaders have a CI and a frequency of communication that is characteristic of collaborators, who are involved in coordinating tasks and assigning responsibilities. Three other members, two leaders and one program manager, play the role of gurus providing guidance to the team: they have a CI value (close to 0.00) and a frequency of interactions (about 400 emails in the observed period) that indicate them as core members leading the team

Figure 7.Contribution Index of the Intestinal Rehabilitation team (x-axis is contribution frequency)

5.4 Cross-Team Comparison

A first comparison across the three team's network structures highlights the similarities and differences. In general, the three teams share a relatively high degree of cohesion, with no cases of isolation, which means all the members in the team are related to the rest of the network. On both the Liver Transplant and Intestinal Rehabilitation teams, there were similar communication patterns for the program leaders, who represent the core team and have a similar high CI. On the Cerebral Palsy team, half of the leaders were lower contributors. They communicated in clusters which were connected through a weak tie (the fourth leader).

Table 2 presents network metrics for each team. As indicated by the Core/Periphery fitness value, the Cerebral Palsy team's topological structure differs from the other teams as it has a less defined configuration around a core of key actors and shows at the same time a sparse periphery. Many networks feature a core/periphery structure, where the core is a dominant central cluster, while the periphery has relatively few connections.

Teams	Nodes (members)	Edges (links)	GBC	Density	Periphery Value
Liver Transplant	26	219	0,66	0,1154	0,3497
Cerebral Palsy	69	479	0,61	0,125	0,2355
Intestinal Rehabilitation	31	142	0,26	0,1527	0,3487

Table 2. Social Network Metrics of the three Teams.

Another similarity between the Liver Transplant team and the Intestinal Rehabilitation team is the high prominence of formal leaders. In both teams, these key members act as information brokers and facilitators of knowledge exchange. In both teams, leaders have extensive ties to other institutions in the health care sector, which contributes to the effectiveness of the teams according to Ancona and Bresman's model (2007).

Figure 8 shows a comparison of group-level social network metrics across the three teams; from January 2010 to July 2010 (time is represented on the x-axis).

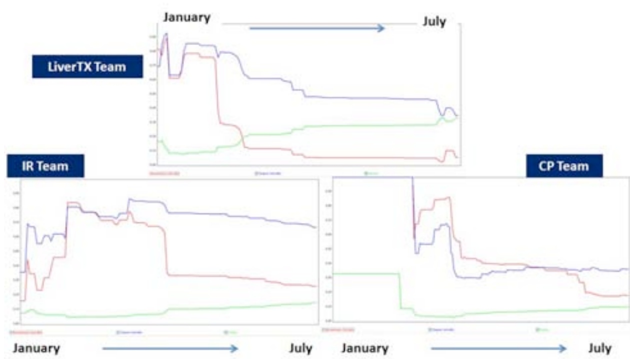

Figure 8. Evolution of metrics: GBC (red line), Density (green line) and Group Degree centrality (blue line). The x-axis indicates the time.

The observed group level metrics are group betweenness centrality (GBC, red line) and group density (green line). The main result indicates that the Liver Transplant team is characterized by a higher GBC (average value 0.6), followed by the Intestinal Rehabilitation team (average value 0.46) and the Cerebral Palsy team (average value 0.3). Nevertheless, if we compare these average values with the fluctuation of GBC over time we can see how the Liver Transplant team, is able to reduce the fluctuation of GBC over time and increase the network density. As shown in Figure 8, the GBC value for the Liver Transplant team starts to decline from February-March 2010, as the network density goes up. This means that the team develops the typical network properties of a COIN (Gloor, 2006) and over time knowledge is exchanged in a more democratic way. A similar trend is visible in the declining values of GBC for the Cerebral Palsy team. After a period of high GBC terminating in May 2010 (with a peak value of 0.8), the pattern of communication within the group became less centralized, remaining close to a value of 0.3. This means that the Cerebral Palsy team was able to reduce the degree of centralization that originally made the team more similar to a star than to a galaxy (Gloor, 2006). The Intestinal Rehabilitation team has a similar declining trend of GBC, though it shows a higher centralization from January to April (GBC between 0.5 and 0.7) with GBC values declining and remaining to 0.3 for the rest of the period. To conclude, these results show that the three teams developed a more democratic and less centralized communication structure during the period of observation.

6. Discussion and Conclusions

This paper describes the communication structure as defined by email patterns of three health care teams in an academic medical center. The focus of this research was to use findings from SNA science to support teams to improve health outcomes for populations of children with complex, chronic conditions. There is potential value of this new knowledge as it relates to Wagner's Chronic Care Model (2001). The model states that improved clinical and functional outcomes for patients are a result of "productive interactions" between patients and effective provider teams (Wagner 2001). This study is an initial step to define the characteristics of effective health care teams.

On the Liver Transplant team, the high centrality of the leaders and the balanced exchange of information among them, in combination with the position of knowledge experts played by the research, program support members, and care delivery members, were all potential positive signs of an effective team. Also, the team showed strong external connections but some of those connections were not shared between members. This indicates that the team is led by members who are engaged in what Ancona and Bresman (2007, p. 7) call "exploration", a process of "learning about customer needs, top management expectations, and their own passions about what they wanted to create". According to Ancona and Bresman, to be effective, members must go outside the team, demonstrating a high level of external activity, which we were able to find in many members of the Liver Transplant team. It seems that the Liver Transplant team has leaders who serve to communicate information but also collaborate both within and outside the team, both critical characteristics of collaborative innovation networks (Gloor, 2006). By doing so, the Liver Transplant team may go beyond its boundaries, adapting structure over time to enable useful external actors to contribute on common projects.

The Intestinal Rehabilitation team acts as a collaborative knowledge network, with a core of members devoted to promoting team development and other members supporting this effort. Similarly to what Gloor found within teams across various industries (2006), well functioning COINs consist of highly motivated creators, collaborators, and knowledge experts. This may be especially relevant with regard to the researcher who is shared by the Liver Transplant and Intestinal Rehabilitation teams. This research team member is a boundary spanner who can act as bridge between the two teams which offers an excellent opportunity to communicate and ensure an effective transfer of best practices. Also, similar to the results in other teams, care delivery members take on the role of knowledge experts, based on their position within the team's Contribution Index plot.

In contrast, the Cerebral Palsy team's communication structure is characterized by scarce multidivisional interaction and a clear polarization around three of the four leaders (see Figure 3). The higher number of nodes in the Cerebral Palsy team compared to the other teams (69, 26, and 31, Cerebral Palsy, Liver Transplant, and Intestinal Rehabilitation, respectively) may be related to the need to involve more people in order to define shared rules and expectations, though it could also be a reflection of a possible dispersion of communication clustered around the three of the four main leaders. The clusters are made of a leader and members from the other domains which may indicate that the team has not merged as one whole but acts as independent ecosystems. This team does not exhibit Ancona and Bresman's principle of exchangeable membership, which would allow Cerebral Palsy team members to shift over time so the required mix of skills and abilities is available when needed (2007). In a mature team, (Tuckman, 1956), a sense of group cohesion arises and members are able to exchange information without relying on a leader's involvement. This excessive reliance of the Cerebral Palsy team members on the four leaders suggests that norms of collaboration across divisions are still in the process of being formulated. Because of this high dependence on leaders, the Cerebral Palsy team seems to be in a phase where leaders are the main coordinators and rules of intra-group interaction are still being developed. The Cerebral Palsy team may find it useful to begin defining common rules of collaboration in order to increase the interaction across divisions permitting a higher degree of cohesiveness. The Cerebral Palsy team may need to work on the third principle of the extended community and expandable tiers. This may be achieved by adopting a flexible structure with a core group that coordinates the rest of the team, another group who can carry out the activities, and others who drop in and out for short periods.

Concerns related to study design must be acknowledged. It is possible that the patterns of email communication are not reflective of the general communications on each team. We have made the assumption that email communication is reflective of team communication since team members are not physically located close to one another and have busy schedules that keep them from meeting each day. Another concern is whether we identified the proper team members as focus for the study. We are confident that identifying the strategic leaders as the hubs was the correct method and found that in most cases they are both the organizationally defined hubs and the functional hubs for their teams. Additionally, by focusing on team members who are at least 20% dedicated to the team, we utilized the communications between the biggest "players" in the effort to build the sociograms. The final question is whether communication patterns actually indicate whether a team is well functioning, effective, and productive. This is one of the primary questions of this research and will hopefully be the case. In the next steps, these determinations will be able to be made.

In summary, our findings indicate that SNA of email communication among actors on a health care team reflect distinct patterns which may help us better understand team function and productivity. As expected, the results of this first observation brought about more questions than answers. Some of these questions are: Do the structure of communication networks in newly formed teams differ from established teams or evolving teams? How does the structure of the communication networks of an effective multidivisional team differ from those on a team located in one division with members that are more accessible to each other? Should there be a difference in the way a geographically dispersed team communicates as opposed to one with members located relatively close together?
Our next steps are to (1) to determine if communication network structure and SNA metrics can predict self assessment of team function (2) to determine if communication network structure and SNA metrics can predict success as measured by clinical outcomes, patient satisfaction, research productivity, and program reputation and (3) to determine if intervention(s) which may improve SNA metrics accelerate the improvement of clinical outcomes, patient satisfaction, research productivity, and program reputation.

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