



COINs2011

Monitoring Changes in the Social Network Structure of Clinical Care Teams Resulting from Team Development Efforts

Francesca Grippa^{a*}, Margaret Palazzolo^b, John Bucuvalas^b, Peter Gloor^c

^a Northeastern University, 360 Huntington Ave, Boston, MA, USA

^b Cincinnati Children's Hospital Medical Center, 3333 Burnet Ave., MLC 2010., Cincinnati, Ohio, USA

^c MIT Center for Collective Intelligence, Cambridge, MA, USA

Abstract

This paper describes the results of a longitudinal observation of team communication structure for two distinct interdisciplinary health care teams at a large academic children medical center in the United States. Our goal was to use the longitudinal analyses to inform teams of opportunities and strategies that strengthen the communication structures a function critical to team effectiveness. For both teams, the members were geographically dispersed across the hospital campus, thereby requiring dependence not only on face to face communication but also on e-mail to promote information flow and facilitate discussion. We analyzed the email archives of two teams (the Liver Transplant/Biliary Atresia and Cerebral Palsy teams) to monitor structural changes in email communication patterns between the 2010 and 2011 observations. Since the first analyses, both teams were designated as strategic priorities by the institution, underwent off site meetings to define and put into execution a strategic plan, initiated processes to improve care delivery and coordination and reviewed the results of the initial SNA. We measured social network metrics such as density, core/periphery structure, distribution of ties, and betweenness centrality and degree centrality. We found that for both teams the communication patterns over the past year had a positive trend, as shown by the increase in density, network resilience and external connectivity.

© 2011 Published by Elsevier Ltd.

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

* Corresponding Author: Tel: +1-617-470-2046
e-mail address: f.grippa@neu.edu

1. Introduction

Recently there's been an explosion of interest in the health care industry regarding the use of network analysis for several medical applications. Some authors have investigated the patterns of relationships among medical staff to recognize mechanistic or organic structures (Cott, 1997). Others have used complexity theory to examine how the quality of care provided by health care organizations is affected by unique network characteristics (Vorst et al., 2011). The typical method used to collect data is the administration of surveys (sometimes self-administered) followed by interviews. The main limitation of this method is the possible introduction of a bias due to forgotten ties (Bernard et al., 1982).

In this paper we conducted an empirical observation of the evolution of team communication structure within two interdisciplinary health care teams at a large academic pediatric medical centers in the US. We collected primary data looking at one year of emails exchanged by members of two health care teams. The goal was to use the longitudinal observation to design strategies that would reinforce the communication structures and improve team effectiveness.

2. Goal

We assessed team communication structure using Social Network Analysis for two distinct interdisciplinary health care teams at a large academic pediatric medical center in the United States . One team serves the population of children with cerebral palsy and the other serves those who have undergone liver transplantation. Our goal was to use the longitudinal analyses to assist these teams in recognizing opportunities and developing strategies to strengthen their communication and improve team effectiveness. For both teams, the members were geographically dispersed across the hospital campus, thereby requiring more dependence on e-mail than face to face communication.

The main research questions leading this study were: How can the growth in connectivity be detected and observed within health care teams using social network analysis? What managerial actions could be designed to reinforce the communication structure of the team? Do teams who have worked together longer respond differently to organizational changes and managerial actions than nascent teams? To address these questions we conducted two studies, observing six months of email exchanges in 2010 and six months in 2011 and compared the structure of the teams at each observations.

3. Theoretical Background

While the team style work is pervasive in the health care environment and discussions about teamwork have been explored since the 1930s, the social network approach to study collaboration within medical teams is more recent and less explored. It is commonly accepted that higher quality and more innovative care occurs when professionals work and learn together, and engage in multidisciplinary meetings to improve clinical outcomes (Brown, 1982, Bell, 2001, Wagner, 2001, Sexton et al., 2006, Makary et al., 2006). We do not know if a network approach to monitor the evolution of team's connectivity provides primary data which will target potential areas of improvement. Social Network Analysis (SNA) has been recently used to observe the structure and evolution of medical teams in various contexts. For example, Cott (1997) applied a social network analysis of 93 health care workers across three multidisciplinary long-term care teams to explore communication processes within teams. The study found that the positive effect of teamwork with respect to collective decision making was limited to a group of higher status professionals.

Recent reports and academic papers have highlighted the importance of working as a team in order to provide high quality and efficient health outcomes for patients (Borrill et al., 2000). A major UK study of teams working in the NHS focused on exploring the factors associated with effective team working. They observed: "*Clearly, if teams are going to work effectively by coordinating their efforts to achieve team objectives, they must have meetings in*

order that information can be shared, decisions can be collectively made, and shared understanding about the tasks can be developed. An important component of team working is building shared understanding of the work, and appropriate processes for delivering high quality patient care (Borrill et al., 2000). The same extensive study found that primary health care comprised of members from multiple disciplines (general practitioners, nurses, physiotherapists, social workers, psychologists etc.) deliver higher quality and are more innovative. Another result of this UK study is aligned with the finding of our research (Palazzolo et al., 2011): only a third of primary health care teams reported having a single clear leader. Most members reported that multiple members led the team.

Aatwin and Caldwell (2005) used interviews, Delphi surveys and direct observation to investigate how health and social care professionals interact. In multidisciplinary teams, they found a degree of inequality in terms of participation among different professions. The authors found that members of the medical profession dominated team meetings while occupational therapists, physiotherapists and social workers did not express opinions, thus were not considered as effective members of the team.

A more recent study conducted by Vorst and colleagues (Vorst et al., 2011) investigated the quality of care provided by organizations involved in healthcare using an approach grounded in the theory of complex networks. The main limitation of the study was the bias introduced by the use of secondary data coming from surveys.

Based on the previous evidence from the SNA literature, we note that there is still a lack of empirical evidence on team effectiveness that rely on primary data sources, such as email archives, phone logs, or face-to-face interactions. Our study contributes to the literature using this primary data. We use emails exchanged by the team leaders and the team hubs.

4. Study Methodology

We analyzed email communication patterns of members from the Liver Transplant and Cerebral Palsy teams at the Cincinnati Children's Hospital Medical Center (CCHMC). To parse emails and collect social network metrics, we used Condor, a software suite that translates email archives 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. The analysis included the email archives of two teams (the Liver Transplant/Biliary Atresia and Cerebral Palsy) during two distinct time periods. We measured social network metrics such as density, core/periphery structure, distribution of ties, betweenness centrality and degree centrality. We also documented the organizational changes that affected the teams since the original assessment in 2010.

To generate our sample for each team, we used a snowball sampling technique. The initial Condor analysis was run on the organizationally defined team leader(s), the hub(s) of each team. Then we used the snowball technique to identify four actors for the rest of the mailboxes in the sample. Once we gathered data, we refined it to include only those actors who committed at least 20% of their effort to the teams' efforts and computed the network metrics using those actors. Finally, we analyzed the sample according to role which was determined by the team members' job descriptions. The five categories of roles we analyzed are care delivery, research, measurement/outcomes management, strategic leadership and administrative/program support.

We compared the social network metrics of the two observations for each team, documented the differences in terms of network density, the centrality values of the team members and documented how individuals and the different roles communicate with one another. We observed the changes in the teams' network structures in light of the team and organization's environment including managerial or organizational level changes to determine their effect on the team's network structure. We then interpreted the data in light of the changes and defined corrective and rewarding measures.

4.1 Conceptual Model

We relied on a conceptual model to guide the analysis and to systematically monitor team communication. This model is based on four steps:

1. *Observe* the structure and the evolution over time of the team’s social network. This step includes the observation of differences in terms of density, group betweenness centrality, core/periphery structure and other individual/team level indicators. Table 1 provides an explanation of the metrics we adopted in this study.
2. *Identify* structural holes, peripheral actors, emerging hubs. This step relies on the empirical evidences from step 1. Based on the initial observation (Step 1.) we monitored the distribution of ties to look for important but unrecognized actors, by observing whether the connectivity or very central members would decrease while actors with roles less organizationally defined as leaders would increase over time as the team develops.
3. *Mirror* the communication behavior through open discussions and involvement of team members. Members were provided with the opportunity to observe their own communication behavior and reflect on the impact of their own behavior on the overall team’s cohesiveness. This was done by presenting the results of the first observation to each team. The step of showing the team themselves “in the mirror” is important to create self-awareness among team members and is a necessary preliminary activity to enable change initiatives and reduce resistance to change (step 4).
4. *Design and Implement* change management initiatives in a collaborative and participative way. The goal of these initiatives is to improve knowledge flow within the team and across its boundaries, targeting members and sub-groups in a more central position in order to equalize the flow and improve connectivity. As noted by Cross et al. (2006): “The idea is never that you want everyone connected to everyone else—people have finite time to spend interacting with others [...]. However, disconnects usually exist across kinds of expertise, cultural values, functions, projects, hierarchy, physical location, and tenure that can keep a community from being as effective as possible. Targeting these gaps, rather than promoting connectivity indiscriminately, yields much more effective and efficient solutions for community development”.

This step is the result of the previous activities of mapping and observing members’ communication behavior. The implementation of change management initiatives to help boost communication is a currently ongoing process at the CCHMC, and will be further discussed in another paper.

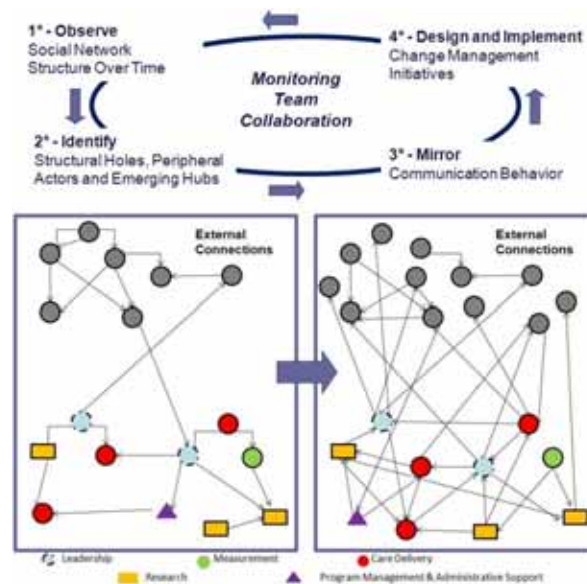


Figure 1. Conceptual Framework

The analysis is based on the use of social network metrics similar to the ones applied to the first part of this research (Palazzolo et al., 2011). Table 1 illustrates the metrics we used in this study, which are differentiated between “team level” and “actor level” metrics.

	Metrics and Structural Indicators	Description	Benefits
Actor Level Metrics	Actor Betweenness Centrality	It is 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.	To recognize gatekeepers and boundary spanners who fill structural holes.
	Degree Centrality	It is the total number of other points to which a point is adjacent. It is also defined as the total number of a point’s neighborhood.	To identify prominent actors with access to many other members.
Team Level Metrics	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.	To 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.	To provide 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.	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).

4.2 Research Setting

Cincinnati Children's Hospital is a 475 bed free-standing children's hospital serving the region of southwest Ohio, northern Kentucky, and southeastern Indiana with a population of 1.4 million people. Cincinnati Children's Hospital is one of the largest pediatric hospitals in the country with over 25,000 admissions, 27,000 surgical procedures, and 700,000 outpatient visits in 2006. The medical center is the sole provider of tertiary and inpatient pediatric care in the region.

4.2.1 Cerebral Palsy Team

Cerebral Palsy (CP) is an umbrella term that describes a non-progressive motor condition that occurs when the motor centers of the brain have been damaged during pregnancy, during childbirth or up to age three. There are many subtypes of CP, but there is no known cure. Treatment is largely limited to preventing complications related to the effects of the patient's disorder, however the CP team at CCHMC has developed an innovative program of care that is focused on improving patient's quality of life and promoting their development in addition to preventing complications.

US prevalence data says 1 in 278 school age children have CP. This means that there are over 2,000 children with CP in the CCHMC primary service area. The Cerebral Palsy team at CCHMC is a recently formed multidisciplinary team assembled to address this need. The team includes providers from the divisions of Physical Medicine and Rehabilitation, Physical and Occupational Therapy, the Aaron W. Perlman Center, Orthopedic Surgery, Neurosurgery. The Perlman Center provides integrated therapy services for young children and assistive technology services for all ages.

The clinic personnel include three nurses (one of whom is a dedicated care coordinator for the state Title V program), two physicians from the Division of Physical Medicine and Rehabilitation, three physical therapists, one occupational therapist (with special expertise in assistive technology), one registered dietitian, and two social workers. An extended team includes a business director, administrative personnel and a research coordinator.

In addition to the clinic team, there is a strategic leadership team comprised of the two physicians from Physical Medicine and Rehabilitation, the clinical director from Physical and Occupational Therapy, the Senior Director of the Aaron W. Perlman Center and the Director of Orthopedic Surgery. While the overall CP program (including OT/PT and Perlman) has a much larger reach, the CP Clinic serves approximately 200 children, about 85% from the immediate area.

The CP team had existed for approximately one year prior to the 2010 observation. Since that time the team has been designated as a "high impact condition specific team" by the institution, which means they will receive additional support from the institution to define programmatic goals and build strategies to achieve them. They have collaborated as the CP Program with the divisions of neurosurgery and orthopedics to develop strategies for growth and development of the CP Center, to improve the health outcomes for their patient population through services and outreach, develop a targeted patient based research program, and to coordinate treatment for their patients.

4.2.2 Liver Transplant and Biliary Atresia Team

The Liver Transplant/Biliary Atresia Team at CCHMC has a high patient volume, with an average of 25 liver transplants per year and provides care to children who require liver transplantation in a radius of approximately 250 miles. More than 500 liver transplant operations have been done at CCHMC since 1986 and the team continues to provide long term follow-up care to this population. Biliary atresia is a disorder of the hepatobiliary duct, detected in infancy and is the most common cause of liver transplant. Approximately 70% of these patients require transplantation by age 10.

The core team includes experienced clinical leaders: four transplant surgeons, nine hepatologists, four pre-transplant nurse coordinators, three transplant coordinators, one social worker, three dedicated research coordinators and one applications/systems analyst. An extended team includes basic scientists and two faculty who are senior investigators, inpatient care nurses, financial analysts, contracting experts, and administrative support personnel. The team currently has funded research from NIH for six patient based studies.

The Liver Transplant and Biliary Atresia teams had been separate until 2010 when they were merged and designated as a strategic priority for the institution. As a result the team has been offered additional financial and

human resources to accomplish their programmatic goals. Prior to this, both teams were well established and had been operating individually and collaborating on individual patient care. In 2010 the Liver Transplant and Biliary Atresia teams met to develop a unified strategy to meet their programmatic goals and followed up by assembling project plans to operationalize them and implement projects and improvements. In addition, they have defined leaders for each section of the team, defined a regular meeting schedule for the merged team, and have built a model to help them better understand and predict the impact of the patient population as they flow through the hospital from diagnosis through either resolution or liver transplant and any following complications.

5. Results

5.1 Cerebral Palsy Team Over Time

The analysis of the Cerebral Palsy team in 2011 shows a network split into three subgroups by leaders (the network does not have a core/periphery structure). This result is similar to the 2010 observation, though the connections among the subgroups are more intense and frequent. The network became more resilient over time as demonstrated by the growth in density, the increase in ties and the centrality metrics which do not change significantly when leaders are removed. Some actors in non-leadership positions play the role of information brokers when their formal leader is removed from the network. For example, when the leader of the Perlman group (right cluster in Figure 2) is removed from the network, two care delivery coordinators and one social worker act as information brokers with the other two clusters. In general, in 2011 when we removed the leaders, no one else gets disconnected, while in 2010 removing the leaders led to 6 people falling out (on average). This means that over time the network is becoming more resilient and information may flow without bottlenecks.

The team's external connections in both the 2010 and 2011 observations are strong and involve a variety of institutions in the health care sector, with a balance between private and public institutions. While some leaders are more internally connected, others play a strong boundary spanning role (the Director of OT/PT and the Director of the Perlman group). This is an important result that is aligned with the findings of research on team "boundary spanning" that has drawn attention to the importance of external rather than internal interactions (Gladstein, 1984; Ancona and Bresman, 2007). Boundary roles are the link between the team and the internal or external environment. They are represented by members who are connected to key individuals outside the organization, helping knowledge being transferred beyond team's boundaries. The importance of boundary spanning roles has been formalized by Ancona and Bresman (2007) with their principles of successful teams: extensive ties, expandable tiers and exchangeable membership.

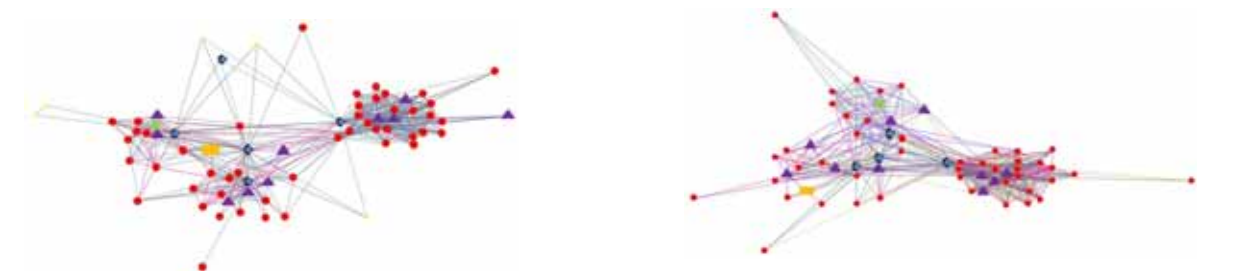


Figure 2. CP team in 2010 (left) and 2011 (right)

Figure 3 illustrates the evolution over time of group level network metrics such as density, core/periphery structure and group betweenness centrality. Between the two observations the connectivity increased by 20% (density increased from 0.125 to 0.1503) and the communication structure became more centralized, as shown by peak in the Group Betweenness Centrality (GBC) values. The Core/Periphery (C/P) values over time indicate that there was a decrease in the number of actors populating the periphery. These results are aligned with the presence of strong connections around the leaders (Figure 2).

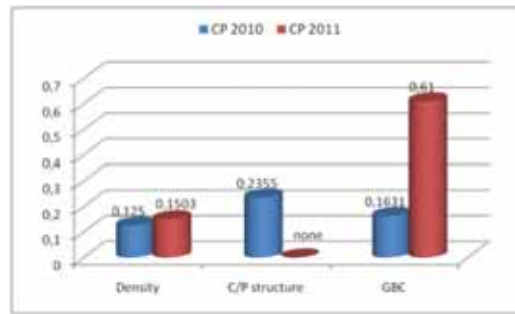


Figure 3. CP Team Network metrics over time

5.2 Liver Transplant Team Over Time

Preliminary results of the Social Network Analysis for the Liver Transplant team indicate a significant increase in density (from 0.1154 to 0.337), higher network cohesiveness as well as an increased number of both actors (from 26 to 35) and ties (from 219 to 401). The team network from 2010 to 2011 shows a lower core/periphery structure (CP from 0.349 to 0.287), indicating that peripheral actors are not sparse and are better integrated into the network than before. The core of the 2011 communication network is composed of four of the six appointed team leaders, a member from the administrative and program support domain and three members from care delivery. The domains, which represent different roles on the team, are also more connected than in 2010, when we observed a slight separation between members of the care delivery domain and the research domain. In both observations, the network periphery is populated by actors from the same domains (i.e. social workers and those involved in the clinical research). The observation that social workers are on the network periphery is aligned with the observations of Aatwin and Caldwell (2005) and may represent a target for improvement into care processes that will be further investigated.

A similar result to the findings from the 2010 observation is the presence of interchangeable formal leaders, which indicates the network is resilient. By looking at their external connections, we noticed that the leaders complement each other in terms of number and type of external actors/institutions to which they are connected. Our analysis also shows the emergence of unrecognized leaders who connect the domains when we remove the hubs. In particular, the application specialist in the Measurement/Outcomes Management domain emerges as an important connector within the team in both observations.

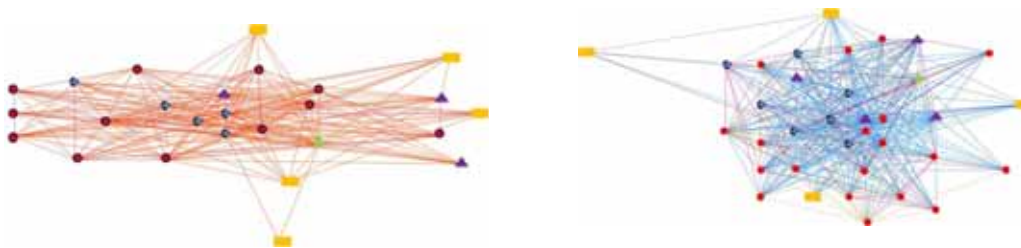


Figure 4. Liver TX/BA in 2010 (left) and 2011 (right)

Over time we observed an increase in the number of information brokers, identified through the betweenness centrality metric. This result provides evidence that the network gets more resilient over time and the team does not rely on one single actor. If one hub leaves the team, there are other actors who can transfer the information.

Figure 5 illustrates an interesting result: density grew over time; the network had a smaller periphery, while GBC dramatically decreased. This indicates that the team became more cohesive and less centralized. As noted in Table 1, Group Betweenness Centrality can help recognize phases in which information is flowing freely and there is high potential for sharing innovative ideas. Thus, it impacts on multiple dimensions, being a good indicator to find

innovative phases within a team (when GBC is low) and defining the stages in which information is flowing without excessive centralization (which is high when GBC is closer to 1).

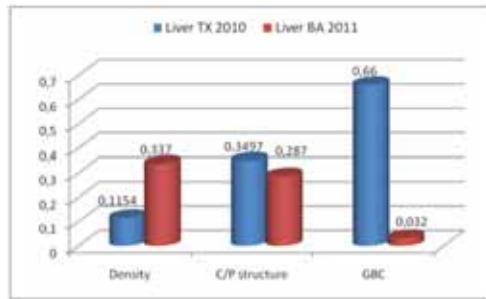


Figure 5. Liver Team Network metrics over time

6. Discussion and Conclusions

We observed that the CP and Liver/BA teams increased their ability to resist to structural changes (i.e. their resilience when leaders are removed), though some areas of improvement have emerged as targets for future improvement. An important target will be to improve inter-role communication, which is a very common issue in the health-care environment. Borrill and colleagues (2000) found that reasons for poor communication within care team included differences in status, power, educational background, and the assumption that the doctors would be the leaders.

In our study, peripheral actors have been identified in both observations and will be objects of future investigation and possibly interventions to help them become more active. Possible actions to consider to improve their involvement are: 1) provide more responsibilities to them; 2) assign two to three peripheral actors to an information broker; 3) consider ways to influence staffing or internal projects to engage these people; 4) develop team processes to ensure that others are aware of the peripheral actors' expertise and (5) examine institutional policies which may impact care delivery.

Some actions taken over the past year have helped the teams develop their communication networks. This is visible in the increase in density and in the stronger ties between domains/roles over time. Specific managerial actions and institutional changes, such as a project to redesign space to improve communication within the CP work environment, have been made in order to optimize knowledge flow and improve workers and patients' satisfaction. These changes in combination with educating the teams about how their communication networks operated after the 2010 analysis (i.e. the "mirroring" phase described in the conceptual model) has resulted in positive changes in the communication networks in the 2011 observation.

This paper applied Social Network Analysis to study collaboration within medical teams, suggesting a new and still unexplored method to observe the evolution over time of internal and external connectivity, with the final aim to design change management programs.

Acknowledgements

We thank all the key members of the teams who shared their email archives. Without their precious contribution, this study would have not been possible.

References

- Aatwin A., Caldwell K., (2005) "Do all health and social care professionals interact equally: a study of interactions in multidisciplinary teams in the United Kingdom", *Scandinavian Journal of Caring Sciences* , 19, 268–273.
- Ancona D. and Bresman H., *X-Teams. How to Build Teams that Lead, Innovate, and Succeed*, Boston, MA: HBS Press, 2007.

- Bell L. (2001) “Patterns of interaction in multidisciplinary child protection teams in New Jersey”, *Child Abuse & Neglect*, 25(1), 65-80.
- Bernard H.R., Killworth P., Sailer L. (1982) “Informant accuracy in social network data V”, *Social Science Research* 11, 30-66.
- Brown T. An historical view of health care teams. In *Responsibility in Health Care Teams* (Agich GJ ed.), 1982, Reidel, Boston, USA, 3–21.
- Burt R.S., 1992. *Structural Holes*, Cambridge MA: Harvard University Press.
- Cott, C. (1997). “We decide, you carry it out”: A social network analysis of multidisciplinary long-term care teams. *Social Science & Medicine*, 45 (9), 1411-1421
- Gladstein, D. (1984) Groups in context: A model of task group effectiveness. *Administrative Science Quarterly*, 29: 499–517
- Gloor P. A., *Swarm Creativity. Competitive Advantage through Collaborative Innovation Networks*, 2006, New York, NY: Oxford University Press.
- Makary MA, Sexton JB, Freischlag JA, Holzmueller CG, Millman EA, Rowen L, Pronovost PJ. (2006b) Operating room teamwork among physicians and nurses: teamwork in the eye of the beholder. *J Am Coll Surg*. 2006 May;202(5):746-52.
- Palazzolo M., Grippa F., Booth A., Rechner S., Bucuvalas J., Gloor P. (2011) Measuring Social Network Structure of Clinical Teams Caring for Patients with Complex Conditions, *Procedia - Social and Behavioral Sciences*, Elsevier, Collaborative Innovations Networks Conference, Savannah GA, October, 2010.
- Sexton JB, Makary MA, Tersigni AR, Pryor D, Hendrich A, Thomas EJ, Holzmueller CG, Knight AP, Wu Y, Pronovost PJ. Teamwork in the operating room: frontline perspectives among hospitals and operating room personnel. *Anesthesiology*. 2006 Nov;105(5):877-84.
- Vorst J.H.L., de Vries T., and Gussekloo J. (2011) Cooperation Instead of Competition, 3(2), 2011.
- Wagner, E. H. Meeting the Needs of chronically Ill People. *British Medical Journal*, 2001, Oct; 27;323(7319):945-6.
- Wasserman S. and Faust K. *Social Network Analysis. Methods and Applications*. 1994. Cambridge MA, Cambridge University Press.