Supporting development efforts of clinical care teams

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Abstract: This paper describes the results of a longitudinal study of team communication structure for two distinct interdisciplinary healthcare teams at a large academic children medical centre in the USA. Our goal was to inform teams of opportunities and strategies that strengthen their communication structure. To this purpose we proposed an operational framework based on four steps: observation, measurement, mirroring and design. We analysed the e-mail archives of two teams to monitor structural changes in e-mail communication over one year. 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 reviewed the results of the initial social network analysis. We found that for both teams the communication network improved over time showing a higher cohesiveness, an increase in density, network resilience and external connectivity.

Keywords: social network analysis; SNA; social networks; COINS; clinical teams; team structure; communication networks; healthcare teams.

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1 Introduction

Recently we observed an increasing interest in the healthcare industry regarding the use of network analysis for several medical applications. Some authors have investigated the patterns of relationships among medical staff to recognise mechanistic or organic structures (Cott, 1997). Others have used complexity theory to examine how the quality of care provided by healthcare organisations is affected by unique network characteristics (Vorst et al., 2011). The typical method used to collect data is still the administration of surveys followed by interviews.

In this paper we conducted an empirical observation of the evolution of team communication structure within two interdisciplinary healthcare teams at a large academic pediatric medical centre in the USA. We collected primary data looking at one year of e-mails exchanged by members of two healthcare teams. We also gathered team members' feedback during focused meetings organised to present the results. Our goal was to use the longitudinal observation to design strategies that would reinforce the communication structures and improve team effectiveness.

2 Research goal

We assessed team communication structure using social network analysis (SNA) for two distinct interdisciplinary healthcare teams at a large academic pediatric medical centre in the USA. One team serves the population of children with cerebral palsy (CP) and the other serves those who have undergone liver transplantation. Our goal was to use the longitudinal analyses to assist these teams in recognising opportunities and developing strategies to strengthen their communication and improve team effectiveness.

The main research questions leading this study were: How can the growth in connectivity be detected and observed within healthcare teams using SNA? What managerial actions could be designed to reinforce the communication structure of the team? To address these questions we built an operational framework that provided some basic guidelines to observe teams' development. We conducted two studies, monitoring six months of e-mail exchanges in 2010 and six months in 2011 and compared the structure of the teams at each observation.

3 Literature review

While the team style work is pervasive in the healthcare 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 et al., 1996; Sexton et al., 2006, Makary et al., 2006).

A less explored area has been the use of a social network approach to monitor the evolution of critical care team's connectivity. SNA is an innovative method to investigate the deep patterns of interactions within and across social organisations. SNA has been defined as "*the disciplined inquiry into the patterning of relations among social actors, as well as the patterning of relationships among actors at different levels of analysis*" [Breiger, (2004), p.506].

The application of SNA requires the manipulation of relational data and the calculation of network metrics providing evidences of different organisational trends. Managers might be able to locate information bottlenecks – when central nodes provide the only connection between different parts of the network – or find organisational subgroups that can develop their own subcultures contrary to the rest of the team.

Network researchers have been proposing helpful network measures to be used in organisational change initiatives (Wasserman and Faust, 1994). These include closeness centrality, betweenness centrality, core/periphery value and density (see Table 1 for further details).

As noted by Cross et al. (2002), organisational analysis should start from the assumption that it might not be a good idea to have everyone in the team or in the organisation connected to everyone else all the time. The goal of SNA is to identify disconnects that usually exist across expertise, functions, department, projects, hierarchy, and physical location. These patterns can keep a team from being effective and efficient in the use of its resources. Observing and measuring the emergence of these holes, rather

than promoting connectivity indiscriminately, is the goal of SNA applied to organisational design and team development.

Social network analysis has been recently used to observe the structure and evolution of medical teams in various contexts. For example, Cott (1997) applied a SNA of 93 healthcare 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., 2001). 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., 2001). The same extensive study found that primary healthcare comprised of members from multiple disciplines (general practitioners, nurses, physiotherapists, social workers, psychologists etc.) deliver higher quality and are more innovative.

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 investigated the quality of care provided by organisations involved in healthcare using an approach grounded in the theory of complex networks (Vorst et al., 2011). The main limitation of the study was the bias introduced by the use of secondary data coming from surveys. Recently, SNA has been applied to study patients and patient communities looking at how information moves within and among them on popular social networking websites (Baebler et al., 2011; Gloor et al., 2010). Our study differs from and complements the studies focused on communities of patients, mainly because of the unit of analysis.

In general, we found a lack of empirical evidence on team effectiveness that rely on primary data sources, such as e-mail archives, phone logs, or face-to-face interactions. Our study contributes to the literature using this primary data as we use e-mails exchanged by the team members (Grippa et al., 2011; Palazzolo et al., 2010).

We base our work on the chronic care model (CCM) (Wagner et al., 1996). This model has been defined to guide quality improvement and support patients with chronic, complex conditions. The CCM is based on six organisation-wide dimensions:

a self-management support

b delivery system design

c decision support

c clinical information systems

d informed patients

e a prepared proactive practice team.

All six dimensions are considered integral to providing optimal care to patients with chronic illness. In particular, we focus on exploring the characteristics of proactive teams and the mechanisms to help them be more effective.

The CCM is aligned with our social network perspective as it adopts an approach that emphasises community linkages. The organisation providing care for chronically ill patients should identify, create and maintain links to community agencies that assist these patients, developing referral systems to external institutions able to improve the network of support.

Our study proposes an operational framework based on SNA that can be used to measure the ability to create extensive ties across departments and exploit knowledge generated by the connection with external healthcare agencies. Our framework is conceptually aligned with research on team boundary spanning (Gladstein, 1984) that emphasises the importance of teams' external rather than internal interactions.

Research on team self-management suggests that autonomy can enable teams to perform more effectively, especially if they can use external knowledge, in the form of task-related information and feedback from sources outside the teams (Ancona and Bresman, 2007; Haas, 2010; Cummings, 2004). In a study conducted in a multinational organisation whose teams operate worldwide, Haas (2010) found that teams with high levels of both autonomy and external knowledge were more effective – both strategically and operationally – than teams with high autonomy but low external knowledge or high external knowledge but low autonomy.

This discussion in the team effectiveness literature suggests that there is still a lack of empirical evidence to understand how teams involved in complex tasks can benefit from acquiring external knowledge.

4 Study methodology

We analysed e-mail communication patterns of members from the Liver Transplant and CP teams at the Cincinnati Children's Hospital Medical Centre (CCHMC). To parse e-mails and collect social network metrics, we used Condor, a software suite that uses e-mail archives to generate sociograms, adjacency matrices, and interactive movies of communication. The analysis included the e-mail archives of two teams (the Liver Transplant/Biliary Atresia and CP) during two semesters. In 2010 and 2011 we measured social network metrics and we documented the organisational changes that affected the teams since the original assessment in 2010.

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.

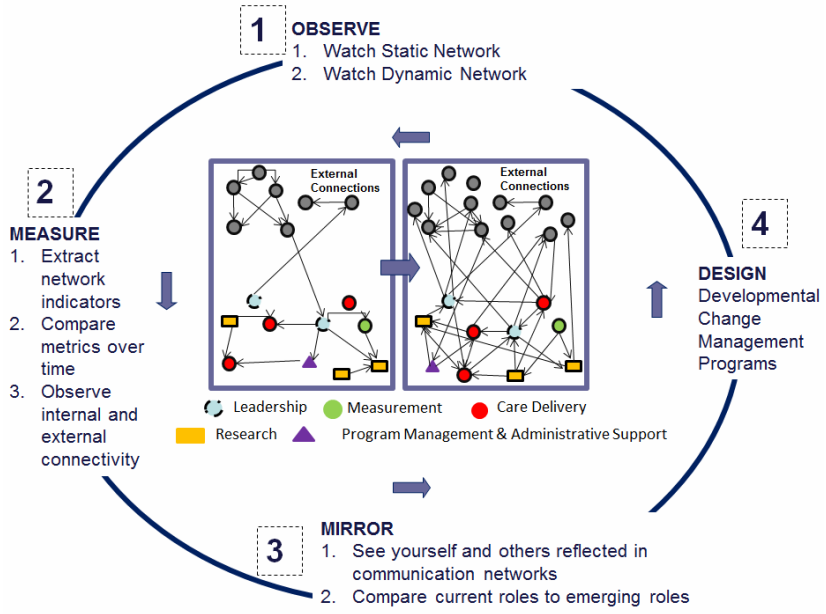
To generate our sample for each team, we used a snowball sampling technique, using insider knowledge and referral chains among team members (Biernacki and Waldorf, 1981). The initial Condor analysis was run on the organisationally defined team leaders, the hubs of each team. Then we used the snowball 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 time to the teams' efforts. We then computed the network metrics using those actors and analysed the sample according to five roles/job descriptions: 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 organisational 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 Operational framework

To conduct the analysis we built an operational framework based on four phases. This framework has been created *ex novo* for this research, though it builds upon the insights from previous studies on virtual mirroring and network analysis (Gloor et al., 2008). These steps are thought to be sequential, with a circular loop from the final phase to the other phases. The reason is that after designing a process improvement initiative (step 4) it is important to plan new observations, measurements and mirroring of people's behaviour over time. Figure 1 illustrates the framework.

Figure 1 Operational framework (see online version for colours)



4.1.1 Observe

This phase involves looking at the structure and evolution over time of the team's social network. It requires the following two actions:

- *Watch static network:* it consists of visualising maps or sociograms of the team social network in order to identify clusters, key actors, fragmentation points, or peripheral members.
- *Watch dynamic network:* it requires observing the evolution of a social network, in order to identify trends in terms of density or individual network centrality.

4.1.2 Measure

This phase requires the following actions:

- *Extract network indicators:* it includes observing the differences in terms of density, group betweenness centrality, core/periphery structure and other individual and team level indicators. Table 1 provides an explanation of the metrics we adopted in this study. They are among the most commonly used indicators to study organisational change (Cross et al., 2002).
- *Compare metrics over time*: it requires following the trends in terms of network metrics' changes: how is density changing over time? Who is becoming more central or more peripheral?
- *Observe internal and external connectivity:* it requires analysing the types of links existing within and across the teams. Based on the availability of data, this phase can provide evidences on the team boundary spanning capabilities, addressing questions such as: who are the information brokers? Who are the emerging hubs?

4.1.3 Mirror

This is the phase when team members see themselves through the lens of their communication behaviour. It starts from the observation of the maps and continues through open discussions with peers. This process helps them reflect on the impact of their communication behaviour on the overall team's cohesiveness. This is done by presenting the results of the observation to team members on a one-to-one basis or during plenary sessions.

This process of letting members look at themselves 'in the mirror' is important to create self-awareness and is a preliminary activity to design process improvement initiatives and reduce resistance to change. In this phase it is possible to compare formal roles – such as nurse, physician, and administrative assistant – with emerging roles – such as information broker, boundary spanner and emerging hub.

This allows members to perceive themselves under a new perspective. As Cross et al. (2002) pointed out researchers can simply put network diagrams in front of team members and ask them to diagnose the patterns they see as well as the issues facilitating or impeding their effectiveness: "*Often one of the most effective interventions is simply to ask people to spend five minutes, either on their own or in groups of two or three, to identify what they 'see' in the map and the performance implications for the group. This process of collectively identifying issues impeding group performance is a very powerful technique for defining behavioral and structural changes to improve effectiveness"* [Cross et al., (2002), p.11].

4.1.4 Design

This is the phase where the team acts upon the results of the previous phases and proposes change management initiatives following a fact-based decision making. The goal of these change management 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 equalise the flow and improve connectivity. This step is the result of the previous phases of mapping and observing members' communication behaviour.

Based on the evidences from steps 1, 2 and 3 it is possible to plan a change that can be defined *developmental.* Following the categorisation proposed by Ackerman (1986), organisations commonly experience three types of change: *developmental*, *transitional* and *transformational*. The first type is more like a fine tuning, where beginning and end points are well known and close to each other. The second type is a change that occurs when current ways of doing things are substituted with something new. Examples are mergers and acquisitions or new product development. The third type is the most radical one. It involves the emergence of a new state that is "*usually unknown until it begins to take shape*" [Ackerman, (1986), p.2].

The implementation of change management initiatives at the CCHMC were meant to help improve communication. It does not require a radical reconceptualisation of the organisation's mission, culture and *status quo,* as the first two types might entail.

The application of our operational framework can support an organisational change directed to improve existing processes "*to do better than or do more of what already exists*" [Ackerman, (1986), p.1]. The stated goal is to improve the communication within the team and across teams' boundaries, facilitating boundary spanning behaviours of their members. These efforts are currently part of an ongoing process at CCHMC, and will be further discussed in another paper.

Table 1 Metrics of social network analysis used in this study

Level	*Metrics*	*Description*	*Benefits*
Actor	*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 recognise 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 neighbourhood.	To identify prominent actors with access to many other members.
Team	*Group betweenness centrality*	The GBC of the entire group is 1 for a perfect star structure, where one central person dominates the communication. The GBC is 0 in a totally democratic structure where all actors display an identical communication pattern.	Plotting the changes of GBC allows observers to distinguish different communication patterns over time.
	Core/periphery structure	A network has a core/periphery structure if the network can be partitioned into a *core* with members densely tied to each other, and a *periphery* with members having more ties to core members than to each other.	To identify the presence of a dense, cohesive core and a sparse, unconnected periphery.

Table 1 Metrics of social network analysis used in this study (continued)

Level	*Metrics*	*Description*	*Benefits*
Team	*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	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 illustrates the metrics we used in this study, which are differentiated between 'team level' and 'actor level' metrics (Wasserman and Faust, 1994; Gloor, 2006; Burt, 1992).

4.2 Research setting

Cincinnati Children's Hospital is a 523 bed free-standing children's hospital serving a population of approximately 1.4 million people. Cincinnati Children's Hospital is one of the largest pediatric hospitals in the country with over 33,000 admissions, 31,000 surgical procedures, and 888,000 outpatient visits in fiscal year 2010. The medical centre is the sole provider of tertiary and inpatient pediatric care in the region.

Our study was designed as part of a program to spread the practices of evidence-based decision making (EBDM) as a way to achieve the best care for children.

4.2.1 CP team

Cerebral Palsy is a non-progressive motor condition that occurs when the motor centres of the brain have been damaged during pregnancy, during childbirth or up to age three. Treatment is largely limited to preventing complications related to the effects of the patient's disorder and to promoting autonomy. 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.

The CP 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 Centre, Orthopedic Surgery, Neurosurgery. The Perlman Centre provides integrated therapy services for young children and assistive technology services for all ages.

The clinic personnel includes three nurses, two physicians from the Division of Physical Medicine and Rehabilitation, three physical therapists, one occupational therapist, 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 Perlman Centre and the Director of Orthopedic Surgery. While the overall CP program 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* in the strategic plan. As a result, they seek to achieve best in class outcomes and receive additional support from the institution to define programmatic goals and build strategies to achieve them. They have collaborated with the divisions of neurosurgery and orthopedics to develop strategies for growth and development of the CP Centre, to improve the health outcomes for their patient population through services and outreach, develop a targeted patient-based research program, and 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 ten.

The core team includes experienced clinical leaders: four transplant surgeons, nine hepatologists, four pre-transplant nurse coordinators, three transplant coordinators, one social worker, three research coordinators and one applications analyst. An extended team includes basic scientists and two faculty members 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 the Biliary Atresia teams combined the efforts to develop a unified strategy to meet their programmatic goals and followed up by assembling project plans to operationalise them and plan process improvements. In addition, they have defined leaders for each section of the team, regular meetings schedule, and have built a model to help them better understand and predict the impact of the patient population.

5 Framework application

In the following paragraphs we will illustrate the application of the operational framework. We will then draw some conclusions based on the observation, measurement

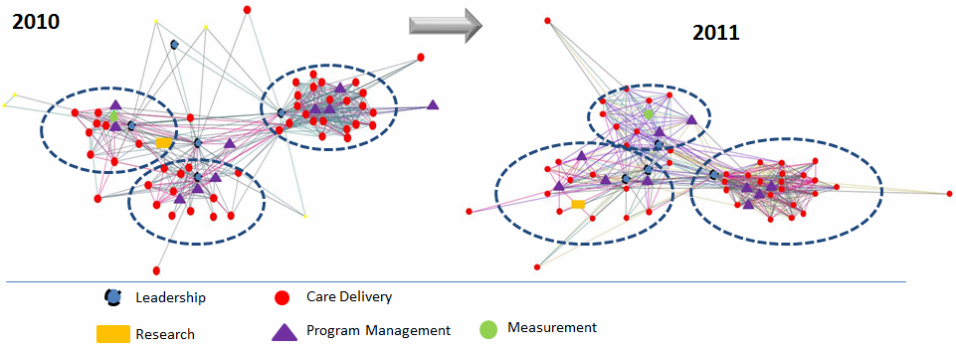
and mirroring of the communication behaviour. Each step provides additional insights into the analysis.

5.1 Observing CP team interactions

The visual analysis of the CP team in 2011 shows a network split into three subgroups by leaders. 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.

When the Perlman group's leader is taken out of the network, two care delivery coordinators and one social worker act as information brokers, heavily interacting with the other clusters. When we removed the leaders in 2011, no one became disconnected, while in 2010 removing the leaders led to six people falling out. This means that over time the network appears more resilient and information may flow without significant bottlenecks.

Figure 2 CP team communication network over time (see online version for colours)



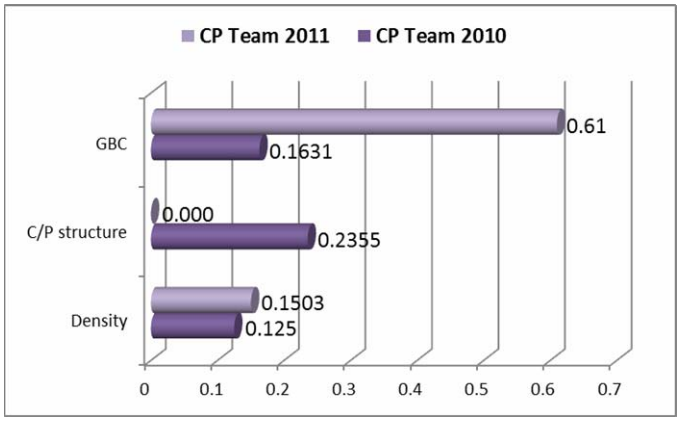
5.2 Measuring CP team communication structure

Looking at the metrics and how they evolve over time is the goal of the second phase. Figure 3 illustrates the evolution over time of three selected group level network metrics: density, core/periphery structure and group betweenness centrality.

These metrics confirmed some of the evidences from phase 1. The network had no core/periphery structure in 2010, being quite cohesive and with no isolated actors. In 2011 the network showed an increasing core/periphery value, indicating the convergence of a group of actors towards the centre (i.e., more people communicating with each other more intensely).

Between the two observations the connectivity increased by 20% (density increased from 0.125 to 0.1503) and the communication structure became more centralised, as shown by peaks in Group Betweeness Centrality values. These results are aligned with the presence of intense connections around the leaders (Figure 3).

Figure 3 CP team network metrics over time (see online version for colours)



The team's external connections in both the 2010 and 2011 observations are strong and involve a variety of public and private institutions in the healthcare sector. While some leaders are more internally connected, others play a strong boundary spanning role with external institutions. The ties between clusters increased over time up to 94%, going in some cases from 18 to 291 in less than a year. Between other clusters ties grew by 70% (from 66 to 221 ties).

5.3 Observing liver transplant team interactions

Preliminary results of the SNA 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 actors (from 26 to 35) and ties (from 219 to 401). The network showed over time a lower core/periphery structure (from 0.349 to 0.287), indicating that peripheral actors were becoming less sparse and better integrated. 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. In both observations, the network periphery is populated by actors with the same role (i.e., social workers and those involved in the clinical research). The observation that social workers are peripheral is aligned with the results of Aatwin and Caldwell (2005) and represents 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. KC is mainly connected to CCHMC members, while JB has strong external connections with hospitals, healthcare associations, universities and research centres within and outside the USA.

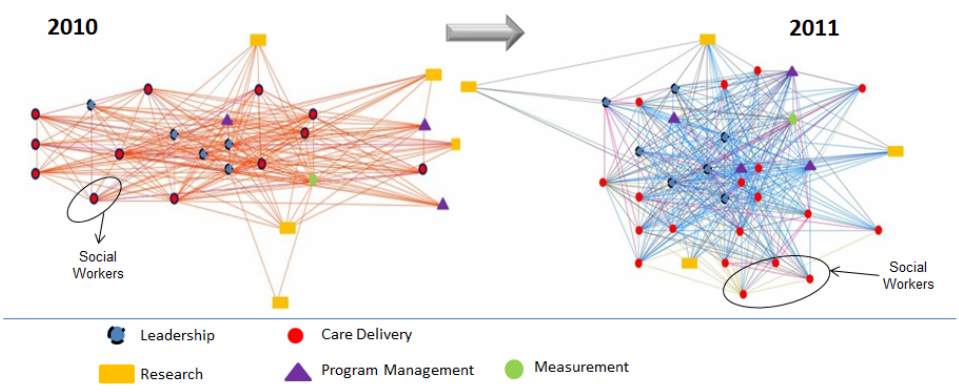
Between 15 and 20% of JB's overall communication occurs with external institutions. The external connections in 2010 of key actors are presented in Table 3.

Table 2 Sample of external connections – liver team, 2011

Code	*Total number of ties*	*Sent to external actors (A)*	*Received from external actors (B)*	*(A + B)*	*% of total*
JB	1,887	237	68	305	16.2
GT	2,620	59	112	171	6.5
KE	2,738	22	115	137	5.0
KC	3,834	63	67	130	3.4

Over time we observed an increase in the number of information brokers, identified through the betweenness centrality metric. Our analysis shows the emergence of unrecognised 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 in both observations.

Figure 4 Liver TX/BA communication structure over time (see online version for colours)



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.

5.4 Measuring liver transplant team communication structure

Figure 5 illustrates an increase in density, a smaller periphery, and a fall in GBC values. This indicates that the team became more cohesive and less centralised. As noted in Table 1, GBC can help recognise phases in which information is flowing freely and there is high potential for sharing innovative ideas.

The external connections of CP team's leaders are presented in Table 3. RR had strong connections within CCHMC and with external institutions. RR appeared to be in the position of a hub, being the third most betweenness central actor and the 1st most connected member to other CCHMC community. Though DK had exchanged more e-mails than RR, these were mainly directed to other CCHMC actors.

Figure 5 Liver team network metrics over time (see online version for colours)

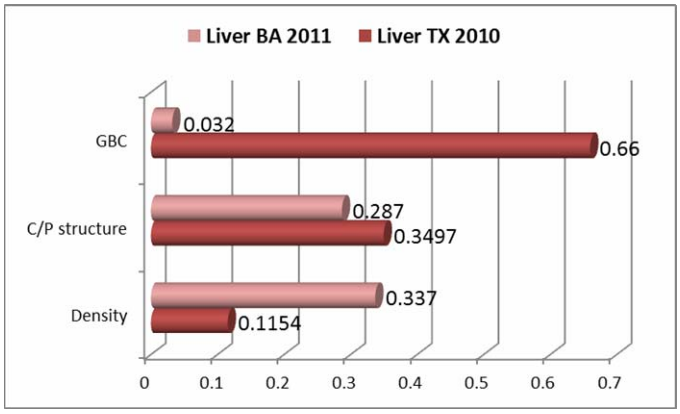


Table 3 Sample of external connections – CP team, 2010

Code	*Total number of ties*	*Sent to external actors (A)*	*Received from external actors (B)*	*Tot (A+B)*	*% of total*
RR	2,905	91	580	671	23%
DK	4,960	138	75	213	4%
LW	3,097	87	308	395	12%

5.5 Mirroring teams' communication structure

In this phase we put the sociograms and the quantitative evidences in front of team members and asked them to reflect on the emerging patterns.

Besides confirming the strategic role of formal leaders, members reflected on emerging roles. An example is provided by GA, an Application Specialist working in the LiverBA team within the field of measurement/outcomes management. Without a formal leadership role, the analysis helped recognise GA's strong position in the team. To confirm this position within the team, we removed various formal leaders from the communication network and we found that the team was still quite dense (368 ties, 34 actors) the clusters were still cross-communicating, and GA was the emerging connector among those clusters.

These results are aligned with the findings of other studies on team boundary spanning (Gladstein, 1984). Boundary roles are the links between the team and the internal or external environment. They are represented by members who are connected to key individuals outside the organisation, helping knowledge being transferred beyond team's boundaries. The importance of boundary spanning roles has been formalised by Ancona and Bresman (2007) with their principles of successful teams: extensive ties, expandable tiers and exchangeable membership. The application of our framework seem to indicate that both the CP and LiverBA teams configure themselves as open teams as they project upwards and outwards. This is demonstrated by two members, KC and JB, both leaders in the LiverBA teams. KC has built strong internal relationships with the team and other CCHMC members, taking care of the task-coordination activity. JB is strongly connected with many *outsiders*. As Ancona and Bresman state "*X-teams have*

emerged to help firms solve complex problems, adapt to changing conditions, innovate, and gain competitive advantage Their entrepreneurial focus helps them getting resources and in seeking and maintaining buy-in from stakeholders" [Ancona and Bresman, (2007), p.9].

Members of both the CP and LiverBA team seemed very motivated to "*see themselves in the mirror*". They demonstrated interest in discussing the results and had many relevant questions about what the different network positions meant and how to interpret communication styles by looking at the sociograms. Even team members, who were normally very sceptical, worked to understand the methods used to calculate the values and get the sociograms. Many of them were not surprised by what they saw in the sociograms. The goal was to foster a change in their behaviour, to facilitate inclusion of peripheral actors and redistribution of workload. This change in communication style was visible in the second observation. In particular with the CP team, the mirroring phase acted as an important enabler of change: members relied less on leaders and modified their individual behaviours in the team. For example, JV, who was a boundary spanner in the first observation, recognised her informal role, though she wasn't really attached to that identity. She verbalised this and it opened up freedom for others to communicate their perception. Before this observation everyone seemed to go through JV because she had been perceived as the person who coordinated everyone's actions.

Another effect of the mirroring phase was to support the evolution of the CP team. This team was newly created and members were learning how to work together while roles were settling out. During the first observation, the team was in an early phase of development and members had to change their work habits to focus more on the CP Program effort. We noticed that during the first observation some leaders were prominently more involved in pushing forward the CP effort. In the second observation, after the mirroring phase, participation from the leaders was more consistent and roles were better defined.

5.6 Design teams development efforts

The phase of planning developmental changes is based on the results of the previous phases. Observing and measuring internal and external connectivity helped support the decision to invest in both teams as *high impact teams*. The main results supporting this are the improvements in terms of cohesiveness: density increased in both teams (by 20% in the CP case). Also, we noticed over time fewer peripheral actors and an increasing number of inter-cluster interactions.

We observed that both the CP team and Liver/BA team 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 healthcare environment. Borrill et al. (2001) 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.

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 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 optimise knowledge flow and improve workers' and patients' satisfaction. On the liver transplant/Biliary Atresia team, the integration of the two teams and the fact that the clinical leaders on both teams are entering their second year might represent an empirical evidence of the development of ties within the team. These changes – in combination with educating the teams about how their communication networks operated after the initial 2010 analysis – has resulted in positive changes in the communication networks in the successive observation. Educating and informing team members about their own communication behaviour is an important benefit of the mirroring phase described in our operational model.

6 Discussion and conclusions

This paper applied SNA 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 initiatives. This type of SNA could be employed not only in support of the development of clinical care teams but also applicable to science teams, to online communities as well as teams in other different domains. The proposed operational framework with its four phases (Observe-Measure-Mirror-Design) can be applied by other researchers to assess structure and evolution of interdisciplinary teams and suggest alternative paths for their growth.

The space redesign project for the CP team is in its design phase, so the results will be visible in the future. Allowing team members *to look at themselves in the mirror* can be considered the first practical change initiative. This worked very well especially on the CP team to motivate the team members to communicate differently and in ways that would address the gaps that they observed.

Another organisational change introduced as a result of this study has been the implementation *ex novo* of a formal team structure. As mentioned by one of the LiverBA leaders: "*SNA informed the definition of a team formal structure around a steering committee and an executive committee*".

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. For example, the roles of social workers have been already changed in order to increase their involvement in the team's operations. Their new formal role is now *case managers*, which should encourage them to act both as coordinators for the required services and connectors between health professionals. The senior management team identified some actions to improve team members' involvement including:

1 providing more responsibilities to them

2 assigning two to three peripheral members to an information broker

3 considering ways to influence staffing or internal projects to engage these people

4 developing team processes to ensure that others are aware of the peripheral actors' expertise

5 examining institutional policies which may impact care delivery.

The main limitation of this study is that it relies on mapping e-mail communication within the teams, with limited access to information about 'what' was exchanged in the interaction. We collected survey data to study the team internal processes, but the response rate was too low to be considered statistically significant.

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