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Health care provider social network analysis: A systematic review

Sung-Heui Bae, PhD, MPH, RN[a,*], Alexander Nikolaev, PhD[b], Jin Young Seo, PhD, WHNP-BC, RN[c], Jessica Castner, PhD, RN[d]

[a] School of Nursing, University of Texas at Austin, Austin, TX
[b] Department of Industrial and Systems Engineering, University at Buffalo (SUNY), Buffalo, NY
[c] Hunter-Bellevue School of Nursing, Hunter College, CUNY, New York, NY
[d] School of Nursing, University at Buffalo, The State University of New York, Buffalo, NY

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ABSTRACT

Objectives: Although considerable progress has been made in understanding networks, their structure, and their development, little has been known about their effectiveness in the health care setting and their contributions to quality of care and patient safety.The purpose of this study was to examine studies using social network analysis (SNA) in the health care workforce and assess factors contributing to social network and their relationships with care processes and patient outcomes.

Methods: We identified all published peer-reviewed SNA articles in CINAHL, PubMed, PsycINFO, JSTOR, Medline (OVID), and Web of Science databases up to April 2013.

Results: Twenty-nine published articles met the inclusion criteria. Current evidence of the health care workforce's social networks reveals the nature of social ties are related to personal characteristics, practice setting, and types of patients. A few studies also revealed the social network effects adoption and the use of a health information system, patient outcomes, and coordination.

Conclusions: Current studies on the social ties of health care workforce professionals include several assessments of inefficiencies. The level of technical sophistication in these studies tended to be low. Future study using enhanced sophistication in study design, analysis, and patient outcome testing are warranted to fully leverage the potential of SNA in health care studies.

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Introduction

In health care settings, social network analysis (SNA) has been used to understand communication and collaboration of health care providers, diffusion of new practice, and knowledge sharing among physicians (Barnett et al., 2012; Cunningham et al., 2012; West, Barron, Dowsett, & Newton, 1999). SNA provides a means of mapping and exposing channels of communication and information flow between people in important groups within an organization (Cross &

* *Corresponding author:* Sung-Heui Bae, School of Nursing, University of Texas at Austin, 1710 Red River Street, Austin, TX 78701.
E-mail address: sbae@nursing.utexas.edu (S.-H. Bae).

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Parker, 2004; O'Malley & Marsden, 2008; Wasserman & Faust, 1994). It explores the types of relationships that generate communication and learning, rather than focusing on the strength of individual relationships (Chambers, Wilson, Thompson, & Harden, 2012). The purpose of this systematic review is to examine studies using SNA in the health care workforce.

The Systems Engineering Initiative for Patient Safety (SEIPS) model of work system and patient safety provides a conceptual framework to link health care providers' social networks with patient safety outcomes (Carayon et al., 2006). The work system's organization, technology and tools, personal provider characteristics, tasks, and work environments must all match and contain an appropriate balance to enhance patient safety. In addition to the social network, the construct of work system "organization" in the SEIPS model includes teamwork, coordination, collaboration, and communication; organizational culture; work schedules; supervisory/management style; and performance evaluation, rewards, and incentives. Thus, the structure of the work system (including the social network of health care providers) impacts work and clinical processes, which subsequently influence patient safety outcomes.

Health care providers' interactions contribute to the culture and knowledge of health care organizations (Barnett et al., 2012). Supporting integration and sustaining collaboration among providers and professionals are also important to guarantee a multidisciplinary approach to health care (Mascia, Cicchetti, Fantini, Damiani, & Ricciardi, 2011). In the hospital environment, multidisciplinary teamwork, efficient communication, and effective interpersonal interactions are critical for patient safety and quality of care. Without good communication and cooperation among members of the health care team, people are not able to share useful information for patient care (Creswick, Westbrook, & Braithwaite, 2009). SNA allows the study of complex communication and interaction patterns in health care settings (Creswick & Westbrook, 2010). Because communication and interaction among health care providers are crucial to improve patient safety and quality of care (Bae, Mark, & Fried, 2010; Castner, Wu, & Dean-Baar, 2015), SNA is an important analytic method that can help identify health care gaps affecting patient safety (Anderson & Talsma, 2011).

SNA is a tool to study the performance and interactions of teams and organizations. Networks comprise a set of nodes that typically represent people or organizations and a set of connections between the nodes defined by observed or reported communication (Dunn & Westbrook, 2011). It often is used as a synonym for collaboration and alliance and to describe relationships between these entities (Cunningham et al., 2012). Social networks are people or groups of people who reveal a pattern of interactions among individuals, groups, or organizations (Newman, Watts, & Strogatz, 2002). It affects the behavior of individuals who are embedded in organizations (Mizruchi & Marquis, 2006). Social networks are important to both influence employees and spread information (West et al., 1999). Through network analysis techniques, researchers have examined social networks focusing on the ties among individuals and organizations, and SNA has been widely used to help improve the effectiveness and efficiency of decision-making processes (Chambers et al., 2012; Freeman, 2004; Scott, 2000; Wasserman & Faust, 1994).

Although considerable progress has been made in understanding networks, their structure, and their development, little is known about their effectiveness in the health care setting and their contributions to quality of care and patient safety (Cunningham et al., 2012). We found several studies conducting a systematic literature review in SNA in health care. For example, Cunningham et al. (2012) studied the structure of networks of health care professionals and the effectiveness and sustainability of networks on quality of care and patient safety. They found that cohesive and collaborative health care professional networks can facilitate the coordination of care and contribute to improving quality of care. Dunn and Westbrook (2011) studied network structure from observation-based case studies as a comparison of observed network patterns against a priori gold standard criteria. However, there is a lack of understanding regarding factors contributing to social networks and its relationships to care process and patient outcomes in terms of patient safety and quality of care. To further elucidate this gap in the science, this review identified and described studies reporting results of an SNA undertaken in a health care setting and assessed factors contributing to social network, the role and influence of social networks in a health care setting, and the relation to how the features of networks may improve care processes and patient safety outcomes.

Methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Statement guidelines (Liberati et al., 2009). The protocol for this systematic review was reviewed by the Health Services Research/Workforce Scholarly Team at the University at Buffalo's School of Nursing.

Search Strategy

Studies were identified in the following electronic bibliographic databases: CINAHL, Cochrane Database of Systematic Reviews, PubMed, PsycINFO, JSTOR, Medline (OVID), and Web of Science. Title, keyword (or subject heading when applicable), and abstract searches were used to identify studies by combining the terms (social network analysis and health care settings). SNA included network analysis, social network(s), and communication network. Health care settings included

health care organization(s), health care facilities, hospital(s), nursing home(s), and clinic(s). The search was conducted in April 2013. The search was limited to only articles published in the English language. An additional search used Cochrane Database of Systematic Reviews with the purpose of finding existing reviews and screening the bibliographies of included articles for references. One article was retrieved from the Cochrane Database. The reference list of selected articles was reviewed to manually identify additional articles. A total of 5,636 references were identified, with 2,349 remaining after duplicates were removed.

Study Selection

Selection Criteria

Studies were deemed appropriate for analysis if the report was a primary research study, published in a peer-review journal, the study setting was a health care facility (e.g., hospital, nursing home, or clinic), and social network analysis was used. Both quantitative and qualitative designs were included.

Study Screening

The results of the search and selection process were managed using EndNote software (Thomson Reuters, Philadelphia, PA) (Version 7.0.1). Two independent reviewers (SB and AN or JY and JC) screened the titles of the 2,349 studies and the titles and abstracts for 155 of these studies to determine if the selection criteria were met (Figure 1). Articles were excluded only if both independent reviewers agreed to exclude; otherwise, a full-text screening was completed to resolve any discrepancy.

Full-text screening was completed on 79 studies independently by 2 reviewers (SB and JY) with input on the method section from a social analysis expert (AN). Any discrepancy was resolved by discussion until consensus was met. Of the 79 full-text studies reviewed, a total of 29 published articles (representing 28 unique studies) were included. Studies were excluded because

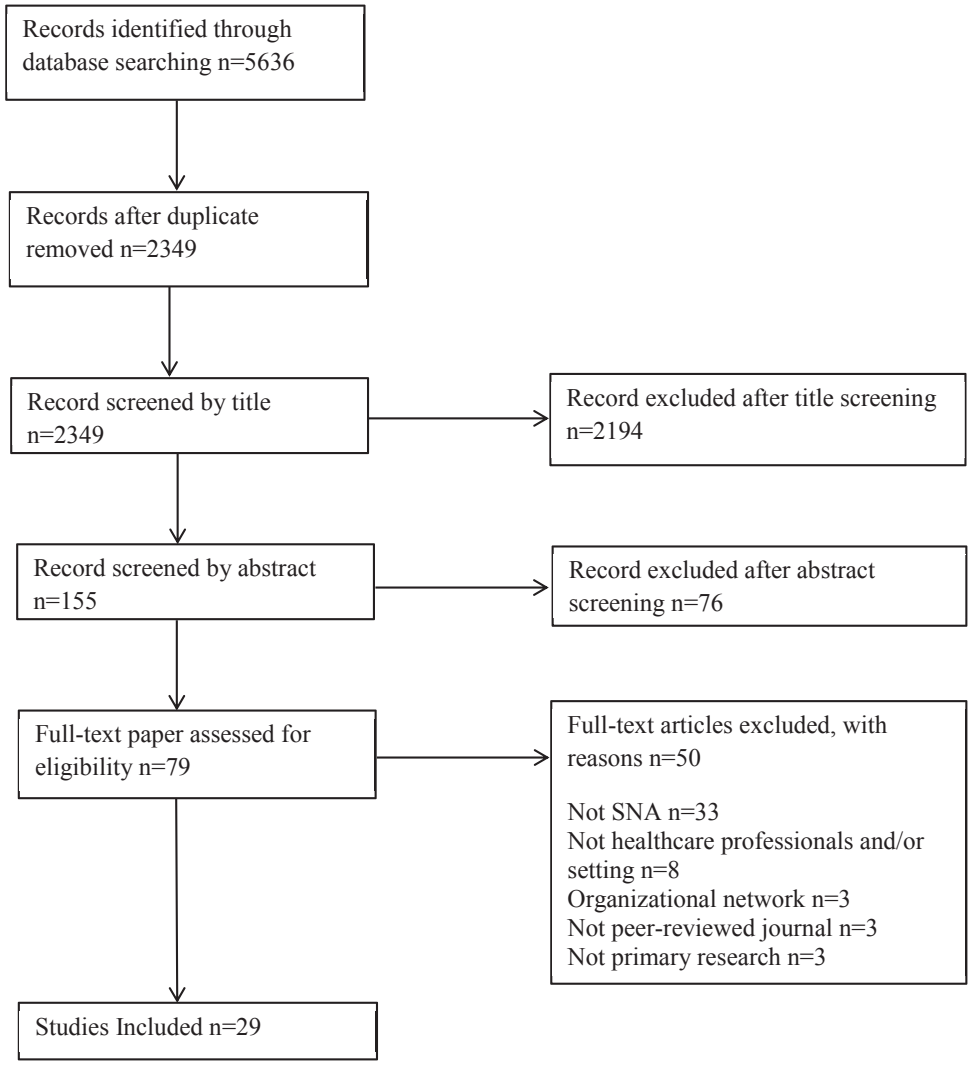

Figure 1 – A flowchart of systematic review.

they did not use an SNA ($n = 33$) or a health care setting ($n = 3$), they were not peer reviewed ($n = 3$), or they were not primary research ($n = 3$). Three additional studies were excluded for a focus on the organizational network rather than including individual health care providers in the network analysis. The remaining studies were assessed for methodological quality.

Quality Appraisal

Of the 29 publications evaluated, Creswick and Westbrook (2007, 2010) were the same study. Therefore, of the 28 studies, 27 included quantitative design elements, and three included qualitative design elements that were evaluated. To clarify, two studies (Baumgart, Denz, Bender, & Schleppers, 2009; Rangachari, 2008) used mixed methods and were evaluated using both quality appraisal instruments.

Methodological quality and risk for bias for the included studies were scored independently by two reviewers (SB and JY). For studies with quantitative designs, the Quality Assessment and Validity Tool for Correlation Studies was used (Cummings et al., 2008; Estabrooks et al., 2001; Estabrooks, Floyd, Scott-Findlay, O'Leary, & Gushta, 2003). This instrument includes 12 items to evaluate the design, sample, measurement, and statistical analysis for quantitative observational studies, with a total of 12 possible points. If the study measured outcomes (either health care providers' outcomes or patient outcomes), two additional items were used to evaluate measurement for a total of 14 possible points. We found that seven studies measured outcomes. Thus, the total number of points scored for those seven studies was divided by 14 points. Others were divided by 12 points. The greater the number, the better the quality of the study was. According to the adapted version of the quality assessment and validity tool criteria (Cummings et al., 2010), studies that scored less than 0.50 were rated as weak, studies that scored 0.50 to 0.75 were rated as moderate, and studies that scored greater than 0.75 were rated as strong. Seventeen articles had moderate methodological quality (mean = 0.55, range = 0.5–0.75). Ten articles were assessed to be of weak methodological quality (mean = 0.39, range = 0.33–0.42). However, because there were no shortcomings in measurement and analysis in those studies, we also included them for the review (mean = 0.49, range = 0.33–0.75).

Qualitative studies were evaluated using Letts et al.'s (2007) 22-item quality appraisal tool focusing on study purpose, literature, design, sampling, data collection, data analyses, and conclusion/implications. The three studies (Baumgart et al., 2009; Naccarella, 2009; Rangachari, 2008) that used qualitative study methods met most of the items.

Data Extraction and Synthesis

Data were extracted by two reviewers (JY and SB) and verified by two reviewers (SB and JC). In-depth analysis data were extracted by a fourth reviewer (AN). Data abstraction included authors, year, country where study took place, participant/professional types, study design, method of data collection, sample size/response rate, main findings, social network theory, level of analysis, analysis model specification, and analysis software used.

Tables 1-3 were developed to synthesize the extracted data. Studies were synthesized by level of analysis; key structural findings of the social network; and relationship among each study's factors, network features, and care process/outcomes. Table 4 includes key SNA terms and definitions relevant to the studies in this review.

Results

Characteristics of Studies

Table 1 summarizes the characteristics of the included studies. Of the 28 studies, there was a main focus on the network to spread information or advice among health care workers ($n = 14$); influence outcomes such as stress, job satisfaction, trust, or prestige ($n = 7$); describe patient referrals and costs associated with the prescribing behavior among health care providers ($n = 2$); or compare patient outcomes such as efficiency through the system ($n = 4$). Settings for the social network studies included hospitals ($n = 19$), outpatient clinic or surgical facilities ($n = 5$), a mix of inpatient and outpatient settings ($n = 1$), long-term care ($n = 1$), or region-wide referral patterns or professional associations ($n = 2$). Of the hospital-based settings, the hospital units studied included operating departments; anesthesiology departments; postsurgical/postanesthesia care units; and dialysis/renal, psychiatric, medical-surgical, pediatric, and emergency departments. The studies took place in North America ($n = 15$), Europe ($n = 8$), Australia ($n = 4$), and Asia ($n = 1$). An equal number of studies included multidisciplinary teams (interprofessional clinicians) as physicians-only participants ($n = 10$). Six studies focused on nursing staff alone, whereas two studies focused uniquely on administrators or infection control specialists.

Research designs for the included studies were cross-sectional ($n = 22$), longitudinal ($n = 3$), mixed methods ($n = 2$), and qualitative ($n = 1$). Only one of the 28 studies used random sampling to select participants (cluster random sampling). Eight studies used more than one type of data collection with survey ($n = 21$), interview ($n = 7$), administrative, or patient record review ($n = 7$); observation ($n = 3$); and simulation ($n = 1$).

Methodological Approaches and Tools Used for SNA

We explored the technical aspects of the analyses performed by the authors of the 29 articles

Table 1 – Overview of Studies

Authors (Year) Country	Setting & Sample	Study Design	Findings
Anderson and Jay (1985a), US	Hospital; 24 private practice physicians with admitting privileges (100% response rate)	Cross-sectional using survey, interview, and administrative records	Physicians grouped by specialty, thus network findings cannot be separated from differences in the work related to specialty practice. Older, more professionally engaged physicians with a lighter patient workload were more likely to initiate referrals and were early adopters of the new technology.
Anderson and Jay (1985b), US	Hospital; 24 private practice physicians with admitting privileges (100% response rate)	Cross-sectional using survey, interview, and administrative records	Physicians who were more socially integrated, or within cohesive groups, adopted the hospital information system sooner. Cohesive groups adopted the hospital information system collectively at around the same time.
Anderson (1991), US	Postsurgical unit; 42 nursing staff (96% response rate)	Cross-sectional using survey and interview	Day shift nurses with high levels of stress are closer to the center of the social network and the nurse manager, indicating they have mobilized social support. Night shift nurses with high levels of stress are on the periphery of the network. Stress for the night shift only is significantly associated with burnout and absenteeism.
Anderson and Talsma (2011), US	OR cases at one hospital linked to OR staff; 4,356 general surgery cases, 1,645 neurosurgery cases, 733 interprofessional OR staff	Cross-sectional using medical records	Neurosurgery teams tended to have members in either the core or periphery, where general surgery had more members in the semiperiphery. Procedures that had an early start time were significantly longer cases and staffed with teams and members that worked together often.
Barnett et al. (2012), US	Physician affiliation with hospitals in hospitals in referral regions; 61,461 physicians affiliated with 528 hospitals in 51 hospital referral regions	Cross-sectional using administrative claims files	Networks in which primary care providers are more central (generally in smaller hospitals) showed an association with lower costs and fewer specialty referrals. An increase of connections per physician was related to an increase in total spending and hospital days.
Barrera & van de Bunt (2009), Netherlands	Dialysis department; 39-42 dialysis nurses, supporting staff, and secretary (90% response rate)	Longitudinal using observation, survey, and interview	Higher degree of trust was found between staff working in the same job category (nurse to nurse and non-nurse to non-nurse). Men are more trusted than women. Trust is built on the person's own positive experience with another, while a third party has a stronger influence on spreading distrust than trust.

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Table 1 – (*Continued*)

Authors (Year) Country	Setting & Sample	Study Design	Findings
Baumgart et al. (2009), Germany	Outpatient OR; All OR interprofessional clinicians for 5,000-6,000 cases	Longitudinal, mixed method using observation, survey, and interview	The change in facility layout increased the number of interactions among OR clinicians and patient handoffs.
Boyer, Belzeaux, Maurel, Baumstarck-Barrau, and Samuelian (2010), France	Hospital-based Psychiatric Department; 104 interprofessional clinicians, social workers, and administrators (69% response rate)	Cross-sectional using survey	Physicians had the highest scores for network centrality, prestige, and clique compared to nurses, psychologists, or social workers. Workers whose time was spent in more than one setting also had higher scores. Age older than 45 years was associated with higher centrality and clique scores.
Creswick and Westbrook (2007 & 2010), Australia	Renal ward; 45 interprofessional clinicians and support staff (96% response rate)	Cross-sectional using survey	Most communication occurred within professional groups in a hierarchical relationship (only 30% of relationships reciprocated). The pharmacist, a junior physician, and three senior nurses were pivotal in this network.
Creswick et al. (2009), Australia	ED; 109 interprofessional clinicians and support staff (94% response rate)	Cross-sectional using survey	All networks demonstrated closest connections were among colleagues from within one's own professional group. Problem-solving network was the most densely connected network followed by the medication advice network and the loosely connected socializing network.
Effken et al. (2013), US	7 medical-surgical care units from 3 different hospitals; 256 patients (76% response rate) and nurses (94% response rate)	Cross-sectional using survey	Handoff communication pattern may have very different effects on different types of patient outcomes. Increased patient self-care associated with more hierarchical communication, increasing ability to manage symptoms related to dense networks with fast diffusion of information. Increased patient satisfaction associated with increased centrality and less hierarchy. Fewer falls and adverse drug events were associated with strong network connections. Fewer adverse drug events were related to cliques.
Fattore et al. (2009), Italy	General practices (GPs); 157 GPs	Longitudinal using administrative data	GPs ability to meet pharmaceutical expenditure targets was not influenced by network centrality but was influenced by other GPs within his/her network.
Hossain and Guan (2012), Australia	ED and outpatient clinic; 100 ED patients and 200 outpatients and interprofessional clinicians of record	Cross-sectional using administrative data	Coordination performance and quality increase with increasing density of the network and degree of connections in the network.

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Table 1 – (*Continued*)

Authors (Year) Country	Setting & Sample	Study Design	Findings
Keating et al. (2007), US	Four clinics within an academic hospital; 33 primary care physician on faculty (response rate 87%)	Cross-sectional using survey	Physicians identified by others as sources of influential information in women's health were more likely to self-identify as experts, care for more women, and have more weekly clinical sessions. Influential discussions were more frequent among physicians practicing in the same clinic site.
Landon et al. (2012), US	Hospital referral region; 4,586,044 Medicare beneficiaries seen by 68,288 physicians practicing in 51 hospital referral regions	Cross-sectional using administrative data	Physicians with ties to each other were more likely to be based at the same hospital and were in closer geographic proximity. Male to male physician ties and ties between physicians near same age were more common. Connected physicians had more similar patient panels in terms of the race or illness burden than unconnected physicians. Network characteristics were strongly associated with size.
Mascia et al. (2011), Italy	Hospitals; 297 physicians at six hospitals (response rate 90.3%)	Cross-sectional using survey	Physicians were more likely to exchange information and advice during patient treatment if they had similar attitudes toward evidenced-based medicine, in the same specialty, in the same organization, and had coauthored peer-reviewed papers. Information exchange was less likely among more geographically distant or similar in years since graduation or number of peer-reviewed articles authored.
Meltzer et al. (2010), US	Hospital; 56 attending physicians in general medicine (79% response rate)	Cross-sectional using survey	Within the social network, physicians clustered with others in same subspecialty, time allocated to research, and gender. Centrality, or betweenness measures, demonstrate usefulness to leveraging organization-wide communication.
Menchik and Meltzer (2010), US	Hospital; 126 physicians (69% response rate)	Cross-sectional using survey	Increased physician reputation in high-prestige hospitals was associated with medical school pedigree, reading several academic journals, and reduced clinical loads while in low prestige hospitals it is associated with more clinical activity and reading several academic journals. Subspecialty was unrelated to reputation.
Naccarella (2009), Australia	Two general practices; 50 interviews with	Qualitative using interview	Key qualities of positive GP work-related relationships included competence, accessibility, goodwill, honesty,

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Table 1 – (*Continued*)

Authors (Year) Country	Setting & Sample	Study Design	Findings
	interprofessional GP personnel		consistency, and communication styles. Network was used for clinical problem solving, obtaining meta-knowledge about the availability of products and services, legitimize a decision, or validate a decision.
Rangachari (2008), US	Four academic hospitals; 12 interviewed and 65 surveyed administrators and interprofessional practice personnel	Mixed methods using interview and survey	Good coding facilities were found to exhibit a network rich in hierarchy and brokerage rather than in density with proactive senior administration. Poor coding facilities experienced blame and lack of involvement from senior administration.
Samarth and Gloor (2009), US	Postanesthesia care unit (PACU); 5 nurses	Cross-sectional using workflow analysis and survey	The social network changes with the underlying workflow. More hierarchical communication is associated with lower patient delay time. With increasing crisis, network density drops. During crisis situations, other PACU nurses become central in the network by interacting informally with the other areas of hospital.
Tighe et al. (2012), US	Anesthesiology department; 55 interprofessional members of a regional anesthesia and perioperative pain medicine service and 29 patients	Cross-sectional simulation constructed with the consensus of 3 attending anesthesiologists and 1 charge nurse	The network was hierarchical, reflecting the teaching structure of the medical system, without much communication redundancy. Removing key attending and fellow physicians resulted in cliques and communication fragmentation across the service, with few alternatives for routing information. Despite the small size of the network, it was complex with many interactions with services in different geographic locations and specialties.
Tsang et al. (2012), Taiwan	Dialysis department; 63 nurses (90% response rate)	Cross-sectional using survey	High centrality in both the work and friendship networks positively affected organizational citizenship behavior. Organizational citizenship behavior, in turn, was associated with increased work satisfaction and decreased stress.
van Beek et al. (2011), Netherlands	35 long-term care units; 380 nursing staff members (53% response rate)	Cross-sectional using survey	Communication and advice networks of nursing staff in long-term care are dense and nonhierarchical. Advice networks were smaller than and not as dense as communication networks. Density of the social networks increased with increasing age of the nursing staff, more part-time staff, and smaller unit size.

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Table 1 – (*Continued*)

Authors (Year) Country	Setting & Sample	Study Design	Findings
			Communication network density was positively associated with job satisfaction.
Walton and Steinert (2010), Canada	Pediatric wards (2); 126 physicians (attending, residents, and medical students) with 18 observation sessions (83% response rate)	Mixed methods using observation and survey	Three different patterns of verbal interaction were observed: attending dominated (most common), shared dominance, and widely interactive. Content of the verbal interaction revolved mostly around lectures or directing patient care. Very little time was spent giving students or residents feedback.
Wensing et al. (2011), Netherlands	Hospital and primary care; 96 interprofessional clinicians (92% response rate)	Cross-sectional using survey	Professionals who treated ≥10 Parkinson disease patients were potentially more prominent and more influential in the network, as indicated by their higher in-degree and out-degree centrality measures. Primary care professionals were less connected in the network than professionals who were affiliated with in hospital.
West et al. (1999), England	UK National Health Service; 100 hospital directors (50 nursing and 50 medicine)	Cross-sectional design with cluster random sampling using survey	Directors of nursing are more central to their networks than clinical directors of medicine. The director of nursing networks are more hierarchical where directors of medicine networks are more densely connected with cliques.
Weimken et al. (2012), US	Hospital; 75 infection preventionists (58% response rate)	Cross-sectional design using survey	The statewide network was limited in density and cohesion, with only three key individuals. Thus, the fragmented network was not adequate for knowledge sharing. Those working in larger or university-affiliated hospitals were less likely to share knowledge with others.

ED, emergency department; OR, operating room.

Table 2 – Summary of Social Network Analysis (SNA)

Authors (year)	Social Network Theories	Level of Analysis	Model Specification/Methodological Approach	SNA Analysis Software
Anderson and Jay (1985a)	Weak ties/structural holes, proximity	Network	Blockmodel analysis, group cohesiveness analysis, multidimensional scaling	CONCOR
Anderson and Jay (1985b)	Information exchange	Actors	Hierarchical clustering, blockmodel analysis	CONCOR
Anderson (1991)	Social support	Actors, network	Smallest space analysis	KYST
Anderson and Talsma (2011)	Weak ties/structural holes	Network	Group cohesiveness analysis, centrality analysis	UCINET, NetDraw
Barnett et al. (2012)	Weak ties/structural holes	Network, organization	Centrality analysis, linear regression	R (Zelig package)
Barrera & van de Bunt (2009)	Trust, information exchange, embeddedness, homophily	Actors, dyads	Social relations model	NA
Baumgart et al. (2009)	Weak ties/structural holes, proximity	Network	Visual inspection	NA
Boyer et al. (2010)	Prestige, information exchange	Actors	Visual inspection, Correlation analysis	UCINET, NetDraw, SPSS
Creswick and Westbrook (2007)	Information exchange, reciprocity	Actors, dyads, network	Group cohesiveness analysis, centrality analysis	UCINET, NetDraw
Creswick et al. (2009)	Information exchange, reciprocity, proximity,	Actors, network, organization	Group cohesiveness analysis, centrality analysis, mixed network hypothesis formulation	UCINET, NetDraw
Creswick and Westbrook (2010)	Small-worldness, reciprocity	Actors, dyads	Group cohesiveness analysis, centrality analysis	UCINET, NetDraw
Effken et al. (2013)	Weak ties/structural holes	Actors, network	Group cohesiveness analysis, centrality analysis, monadic hypothesis testing	ORA
Fattore et al. (2009)	Social capital, information exchange, structural equivalence	Actors, dyads, network	Monadic, dyadic and network hypotheses testing, network regression analysis	UCINET, NetDraw
Hossain and Guan (2012)	Coordination, information exchange	Network	Group cohesiveness analysis, centrality analysis, monadic hypothesis testing	UCINET, NetDraw
Keating et al. (2007)	Information exchange, proximity	Actors, dyads	Mixed hypothesis testing, network regression	Unspecified P2 logistic regression software, NetDraw
Landon et al. (2012)	Information exchange, homophily, weak ties/structural holes	Actor, network, organization	Mixed hypothesis testing, group cohesiveness analysis, centrality analysis	SAS
Mascia et al. (2011)	Information exchange, reciprocity, homophily	Actors, dyads, network	MRQAP regression, group cohesiveness analysis	UCINET, NetDraw
Meltzer et al. (2010)	Team formation, information exchange, weak ties/structural holes	Network	Influence maximization, group cohesiveness analysis, centrality analysis	Pajek
Menchik and Meltzer (2010)	Prestige, information exchange	Network, organization	Linear regression, centrality analysis	NA
Naccarella (2009)	NA	Actors	Visual inspection	NetDraw
Rangachari (2008)	Resource exchange, information exchange, weak ties/structural holes, subgoals theory, transitivity	Network, organization	Structural equivalence analysis, group cohesiveness analysis	UCINET, NetDraw
Samarth and Gloor (2009)	Trust, information exchange	Network, organization	Group cohesiveness analysis, centrality analysis	CONDOR
Tighe et al. (2012)	Information exchange, resilience	Network	Krackhardt hierarchy structural analysis, group cohesiveness analysis	ORA, JMP

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Table 2 – (Continued)

Authors (year)	Social Network Theories	Level of Analysis	Model Specification/Methodological Approach	SNA Analysis Software
Tsang et al. (2012)	Weak ties/structural holes, social support, information exchange	Actors, network	Monadic and network hypothesis testing, structural equivalence analysis, group cohesiveness analysis, centrality analysis	UCINET, NetDraw
van Beek et al. (2011)	Social support, information exchange	Actors, network	Network hypothesis testing, group cohesiveness analysis	UCINET, NetDraw
Walton and Steinert (2010)	Information exchange	Network communication	Centrality analysis	UCINET, NetDraw
Wensing et al. (2011)	Information exchange, reciprocity, transitivity	Actors, network	Group cohesiveness analysis, centrality analysis	UCINET, NetDraw
West et al. (1999)	Social capital, information exchange, embeddedness	Actors, dyads, network	Mixed and network hypothesis testing, group cohesiveness analysis, centrality analysis	NA
Weimken et al. (2012)	Weak ties/structural holes, Information exchange	Actors, network	Key player analysis, group cohesiveness analysis, centrality analysis	UCINET, NetDraw

NA, not applicable.

(28 studies) that met our search criteria (Table 2). We distinguished four levels of analysis of social network data: actor, dyad, network, and organization levels, with the latter encompassing the batch analyses of multiple networks. The numbers of articles that incorporated metrics/characteristics pertaining to these four levels (actor, dyad, network, and organization levels) were 18, 7, 23, and 6, respectively.

The vast majority of articles included the identification and interpretation of clusters and social influence effects. Studies on the interpretation of clusters allowed the authors to make judgments about the validity of weak ties/structural holes theories ($n = 10$) and study network member embeddedness ($n = 2$). Studies of social influence effects tested the theories of information exchange ($n = 21$) and resource exchange ($n = 1$) and explored the notion of trust between network members ($n = 2$). A group of articles focused on centrality metrics interpretation, relying on theories of social capital ($n = 2$), social support ($n = 3$), and studying prestige ($n = 2$). Five articles worked to distill network formation principles, studying in-network reciprocity, proximity, transitivity, homophily, and small-worldness theories.

Eleven software tools were used in the reported work across the 25 articles that identified the tools they used. The most widely used tool was UCINET (Analytic Technologies, Inc., Lexington, KY; $n = 14$) with its visualization add-on NetDraw (Analytic Technologies, Inc., Lexington, KY; $n = 16$). Other SNA tools used were ORA (Center for Computational Analysis of Social and Organizational Systems [CASOS], Institute for Software Research International [ISRI], Pittsburgh, PA; n = 2), Pajek (http://mrvar.fdv.uni-lj.si/pajek/; n = 1), and CONDOR (n = 1). The nonspecialized statistical analysis tools included SPSS (IBM Corp., Armonk, NY; $n = 1$), JMP (SAS Institute Inc., Cary, NC; $n = 1$), R (R Foundation for Statistical Computing, Vienna, Austria; $n = 1$), CONCOR (International Statistical Programs Center [ISPC] of the U.S. Bureau of the Census, Washington, D.C.; $n = 2$), and KYST (Bell Laboratories, Murray Hill, NJ; $n = 1$).

Indicating the level of technical complexity of the performed analyses, some articles mainly relied on visual inspection of the constructed networks (n = 3), others reported centrality measure values ($n = 16$) and group cohesiveness metric values ($n = 16$), and most advanced studies formulated and tested network hypotheses ($n = 9$).

Relationship among Factors, Network Feature, and Care Process/Patient Safety Outcomes

We also explored the factors significantly contributing to social network and any outcomes related to such social network in regard to care processes and outcomes (Table 3). The most common factors that were

Table 3 – Relationship among Factors, Network Feature, and Care Process/Outcomes

Authors (year)	Factors (A)	Social Network Feature (B)	Care Process/Outcomes (C)	Relationships*	
				A → B	B → C
Anderson and Jay (1985a)		Centrality of network location	Adoption and use of a computer-based hospital information system		Positive
Anderson and Jay (1985b)		Centrality of the referral and consultation network	Diffusion process		Positive
Anderson (1991)		Central location in support network from coworkers and broad staff	Coping with stress		Positive
Anderson and Talsma (2011)	Length of care	Team coreness, how often the team worked together		Positive	
	Start time (later in the day)	Team coreness		Negative	
	Registered nurses			Positive	
Barnett et al. (2012)		Median adjusted degree of network	Medicare spending, hospital days, physician visits		Positive
		Betweenness centrality of network	Overall spending, spending on imaging and tests, physician visits, and Medical specialist visits		Negative
Barrera & van de Bunt (2009)		Communication relations and past experience	Learn to trust (distrust)		Positive
Baumgart et al. (2009)	Operating room structure (centralized)	Operating room interdependency		Positive	
Boyer et al. (2010)	Older age	Centrality and clique of health care professional relationship network		Positive	
	Physicians, Working transversal units	Centrality, prestige, and clique of health care professional relationship network		Positive	
Creswick and Westbrook (2007)	Within professional groups	Medication-related advice seeking network		Positive	
Creswick et al. (2009)	Within professional groups	Problem-solving network, medication advice network, socializing network		Positive	
Creswick and Westbrook (2010)	Between professional groups	Medication advice-seeking interactions		Negative	
Effken et al. (2013)		Communication network – clustering coefficient, cliques, triads	ADEs		Negative
		Communication network—component count strong	Falls, symptom capacity		Negative
		Communication network—component count weak, fragmentation, hierarchy, isolates	Symptom capacity		Negative

(*continued on next page*)

Table 3 – (*Continued*)

Authors (year)	Factors (A)	Social Network Feature (B)	Care Process/Outcomes (C)	Relationships*	
				A → B	B → C
		Communication network—density, diffusion, centrality in degree			Positive
		Communication network—diffusion, eigenvector centrality	Simple self-care, complex self-care		Negative
		Communication network—hierarchy			Positive
		Communication network—hierarchy	Well cared for—individual care		Negative
		Communication network—eigenvector centrality			Positive
Hossain and Guan (2012)		Social network—density	Coordination performance, coordination quality, flights		Negative
		Social network—degree	Coordination performance, above average time, coordination quality, flights		Positive
		Social network—network centralization	Flights		Negative
Keating et al. (2007)	Within physicians in the same clinic, physicians having more weekly clinical sessions	Discussion network		Positive	
Landon et al. (2012)	Male, physicians, at the same hospital, in close geographic proximity, similar practice intensity, taking care or similar racial compositions, patient age and percentage of Medicaid patients, similar patients	Patient sharing network		Positive	
Mascia et al. (2011)	Attitude toward evidence-based medicine, field of specialization, same affiliation, directorate, coauthorship	Professional network of collaborate—density		Positive	
	Years since graduation, managerial role, number of publications			Negative	
Menchik and Meltzer (2010)	Higher-prestige hospital, percent of time doing clinical work in higher prestige hospitals	Esteem—in-degree centrality		Negative	
	Number of journals read/month, prestige of medical school in higher-prestige hospitals			Positive	
Tighe et al. (2012)	CN failure at one, two, or three level	Degree centrality, betweenness Centrality, nodal cognitive demand		Negative	
van Beek et al. (2011)	Number of residents, number of nursing staff	Density of communication network, density of advice network		Negative	
Wensing et al. (2011)	Number of PD patients (≥10)	Size (one-step reach), number of connection (ties), Two-step reach, indegree centrality, outdegree centrality, inreach centrality (2 steps), betweenness centrality		Positive	

(*continued on next page*)

Table 3 – (*Continued*)

Authors (year)	Factors (A)	Social Network Feature (B)	Care Process/Outcomes (C)	Relationships*	
				A → B	B → C
		Reach efficiency		Negative	
	Setting of care delivery (hospital setting)	Size (one-step reach), number of connection (ties), density, two-step reach, in-degree centrality, out-degree centrality, in-closeness centrality, out-closeness centrality, in-reach centrality (two steps), out-reach centrality (one step), betweenness centrality		Positive	
		Reach efficiency		Negative	
West et al. (1999)	Occupation group (nursing)	Density		Negative	
		Degree centralization		Positive	
Weimken et al. (2012)	Attending local chapter meeting regularly	In-degree centrality, eigenvector centrality		Positive	
	Worked longer in current position (≥5 years)	In-degree centrality, out-degree centrality, eigenvector centrality		Positive	
	Using national healthcare safety network	In-degree centrality		Positive	
	Affiliated with university	Out-degree centrality		Negative	

CN, Critical node; PD, Parkinson's disease.
* Significance association at $p < .05$.

Table 4 – Key Social Network Analysis Terms and Definitions

Term	Definition
Density	Extent to which individuals are concentrated (network wide)
Connectedness	Extent to which a given individual is connected to peers
Isolates	Individuals who are not connected to anyone in the network
Centrality	Any measure that valuates an individual's network position
Betweenness Centrality	Measure that favors network positions that lie at the crossings of multiple shortest paths connecting the individuals in a network
Reciprocity	Extent to which the direct relationships are bidirectional
Coreness	Measure that distinguishes networks in which some individuals are well interconnected (forming a core), whereas the others have very few direct relationships between each other (forming a periphery)
Clustering	Procedure that works to identify cohesive subgroups in a network
Hierarchy	Top-down pattern in the relationship structure between individuals in a network
Structural holes/weak ties	Concepts that describe the absence or rarity of connections between cohesive subgroups in a network
Embeddedness	Concept that describes how an individual's directly connected peers relate to each other
Proximity	Concept that describes how close the individuals or network subgroups are to each other
Homophily	The tendency of similar individuals to have a relationship
Transitivity	The tendency of individuals who maintain relationships with the same third person to also have a relationship
Small worldedness	The property of a network to have high clusterization while maintaining a low diameter
Clique	Any network subgroup in which all individuals are connected to each other
Diameter	The length of the longest shortest path in a network

identified were related to the health professional characteristics and setting/patient type.

Health Professional Characteristics and the Social Network

Studies that included interprofessional team members, physician-only, and nursing staff–only participants revealed both different foci on the type of social network and how the professionals' characteristics influence the social network. Interprofessional studies revealed that hierarchical relationships among health care professionals were common (Creswick & Westbrook, 2007, 2010; Rangachari, 2008; Tighe, Smith, Boezaart, & Lucas, 2012), particularly for networks involving nursing administrators (West et al., 1999). Individuals were most connected to others in the same profession, such as nurse to nurse and physician to physician (Creswick & Westbrook, 2007, 2010; Creswick et al., 2009). In communication networks (e.g., medication advice-seeking network), there were fewer interactions between different professionals than among one's own profession (Creswick & Westbrook, 2010).

Physician-only studies revealed a strong influence of peers with similar characteristics and close geography in spreading information and innovation (Anderson & Jay, 1985a, 1985b; Landon et al., 2012; Mascia et al., 2011; Meltzer et al., 2010). Physician connections are strengthened if in the same clinical site or geographically close (Keating, Ayanian, Cleary, & Marsden, 2007; Landon et al., 2012), specialty (Mascia et al., 2011; Meltzer et al., 2010), and similar attitudes toward evidence-based medicine (Mascia et al., 2011). Physicians who worked in the same clinic, had more clinical sessions or attended local meetings, and geographically worked closely had higher levels of patient sharing and discussion (Keating et al., 2007). A greater number of connections led to increased costs and referrals, except when primary care providers were more central to the network (Barnett et al., 2012). In addition, several physician-only studies focused on reputation and prestige (Menchik & Meltzer, 2010). Social network cohesion among physicians led to adopting innovation around the same time and similar prescribing behaviors (Anderson & Jay, 1985b; Fattore, Frosini, Salvatore, & Tozzi, 2009). In addition, physicians who had assumed a managerial role or were further from graduation showed a lower propensity to collaborate with others (Mascia et al., 2011).

Studies investigating nursing staff only described dense networks, with each nurse connected to many other nurses (Anderson, 1991; Barrera & van de Bunt, 2009; Samarth & Gloor, 2009; Tsang, Chen, Wang, & Tai, 2012; van Beek et al., 2011). Studies of social support and trust networks were found among nursing staff–only studies and not addressed in interprofessional or physician-only studies (Anderson, 1991; Barrera & van de Bunt, 2009; Samarth & Gloor, 2009; Tsang et al., 2012; van Beek et al., 2011). Nurse network communications shifted to a more hierarchical form with increasing workload or crisis (Samarth & Gloor, 2009), resulting in greater efficiency (Samarth & Gloor, 2009) and increased patient self-care (Effken, Gephart, Brewer, & Carley, 2013). Centrality in the social network was associated with increased work satisfaction and organizational citizenship for nurses (Tsang et al., 2012), ability to buffer work-related stressors (especially for day-shift workers; Anderson, 1991; van Beek et al., 2011), and increased patient satisfaction (Effken et al., 2013). Affiliations tended to

occur between individuals with similar characteristics, such as job category (licensed practice nurse or assistive personnel; Barrera & van de Bunt, 2009). However, less density was seen in nurse advice (compared with general communication) networks (van Beek et al., 2011), with fewer adverse drug events occurring on units with higher numbers of cliques (Effken et al., 2013).

Setting/Patient Type and the Social Network

In the operating room, the characteristics of the interprofessional social network were influenced by the type of surgical specialty team (Anderson & Talsma, 2011) and facility layout (Baumgart et al., 2009). Overall, registered nurses constituted the majority of core interdisciplinary team members in general surgery and neurosurgery groups (Anderson & Talsma, 2011). Team coreness and centrality were associated with increased length of operating room cases (Anderson & Talsma, 2011).

Additional setting-specific findings ranged from the emergency department to across multiple hospitals. In the emergency department, increasing density, or close ties among many people, among the interprofessional network enhanced efficiency and care coordination (Hossain & Guan, 2012). In both the emergency department and renal ward, communication networks such as medication advice seeking, problem solving, and discussion network were stronger within professional groups than between professional groups (Creswick & Westbrook, 2007; Creswick et al., 2009). In long-term care, fewer numbers of health care providers (residents and nursing staff) who worked together were associated with denser communication and advice networks as well as greater nurse job satisfaction (van Beek et al., 2011). In a study across hospitals, those settings that participate in health care safety network were associated with increased team coreness and centrality, indicating individuals are highly connected (Wiemken, Ramirez, Polgreen, Peyrani, & Carrico, 2012).

Physician prestige depended on the practice setting. Prestige was elevated with increased journal reading in all settings, more patient contact time in specialty and lower overall prestige settings (Keating et al., 2007; Menchik & Meltzer, 2010), and elevated with less patient contact in research-intensive settings (Menchik & Meltzer, 2010). Regarding patient types, when physicians took care of patients with similar age, race, and type of health insurance (percentage of Medicaid patients) with other physicians, they had greater levels of patient sharing within their network (Landon et al., 2012).

Care Process and Patient Safety Outcomes Related to Social Network

We also explored which outcomes were examined in a relationship with social network in a health care setting. The following outcomes were found: adoption and use of a computer-based hospital information system (Anderson & Jay, 1985a, 1985b); coping with stress (Anderson, 1991); health care use and cost (Barnett et al., 2012); trust (Barrera & van de Bunt, 2009); patient outcomes such as safety, symptom management, self-care, and patient satisfaction (Effken et al., 2013); and performance of coordination and quality of coordination (Hossain & Guan, 2012).

Network location was found to have a significant effect on both the adoption and diffusion of a hospital information system (Anderson & Jay, 1985a, 1985b). A central location in a support network also was related to coping with stress positively (Anderson, 1991). The degree of network was positively related to health care use (hospital days and physician visits; Barnett et al., 2012). Communication relations and past experience were positively related to learn to trust (Barrera & van de Bunt, 2009). Regarding the communication network, density and centrality of network were related to greater levels of symptom capacity (Effken et al., 2013). The degree of social network was related to greater performance and quality of coordination (Hossain & Guan, 2012).

Social network features adversely related to outcomes are as follows. Betweenness centrality of network was negatively related to health care use (physician visits and Medical specialist visits; Barnett et al., 2012). Clustering and hierarchy of the communication network contributed to care outcomes adversely (e.g., symptom capacity, well cared for individual care, and adverse drug events; Effken et al., 2013). Density and centralization of the social network were negatively related to the performance and quality of coordination (Hossain & Guan, 2012).

To sum up, several studies had examined the factors contributing to the social network. Major factors contributing to the network included characteristics of health care professional and patient types as well as care setting. Relatively fewer studies examined the effects of social network on the adoption and use of a health information system, patient safety outcomes, and coordination.

Discussion

This systematic review adds valuable knowledge in the current literature. We comprehensively synthesized studies of health care providers' social networks in the health care setting. We also deeply investigated the factors and relationships contributing to the social network and patient safety outcomes.

Studies were conducted to observe, describe, and simulate the social network. Most studies were cross-sectional in nature, with only three longitudinal designs. There is considerable risk for bias in the 28 included studies. There were no studies that used an intervention to attempt to change the structure or

function of the social network and no designs that used experimental study design with a control group.

Several experimental or interventional studies would be appropriate with an SNA approach. Examples include testing alterations in staff schedules to closely align cohesive teams, structured teamwork training and interventions, or structured communication tools (such as TeamSTEPPS [Agency for Healthcare Research and Quality, Rockville, MD] tools; Agency for Healthcare Research and Quality, 2006; Castner, Schwartz, Foltz-Ramos, & Ceravolo, 2012). Additional approaches include the development and implementation of tailored behavior change interventions (Chambers et al., 2012). To implement the interventions, researchers may need to change the current layout in health care settings and may have to use a longitudinal study design. SNA studies that involve altering the physical architecture of a unit present unique difficulty in finding appropriate study sites.

Although most of the studies in our review focused on the hospital setting, the studies took place in diverse settings, spanning four different continents. This global interest on health care provider social networks manifested in a wide diversity in the type of network studied as well. We found that only one study was conducted in a long-term care setting. Future study is needed in the long-term care setting as well as on the overall influence of health care social networks on patient safety and quality of care.

Overall, the level of technical sophistication in the practical studies of observed networks tends to be low. The analyses based on basic centrality metric computations and clustering algorithms dominate the existing literature. Notably, UCINET is seen as the most popular software tool for SNA. However, its key strength lies mainly in the ability to test a wide array of network hypotheses and not in the description of underlying mechanisms/theories that could explain network formation. More recently, theory and tools such as SIENA and MAGFIT can shed insights into the longitudinal dynamics of social network evolution and identify the network characteristics and actor attributes that play significant roles in network emergence and growth.

Interestingly, the reviewed analyses appear to be purely descriptive; authors report on the inefficiencies in the existing communication structure between professionals but do not suggest what structure could be optimal and how it can be achieved through organizational changes or policies. There are several teamwork training and communication interventions that would be appropriate to measure using SNA, such as TeamSTEPPS communication initiatives or simulation training (Agency for Healthcare Research and Quality, 2006; Kalisch, Aebersold, McLaughlin, Tschannen, & Lane, 2015). To improve communication and collaboration among health care providers, it is critical to find the optimal structure of communication under a certain health care setting. This knowledge can contribute eventually to improve patient safety and quality of care. Meanwhile, the research in this direction could be particularly useful, especially if the improvements in organization structure can influence the team/organization performance (which multiple studies conclude or imply).

In this review, we found that several key factors contributed to the structural features of the social network. For example, in the operating room, the type of surgical specialty team (Anderson & Talsma, 2011) and facility layout (Baumgart et al., 2009) were critical factors contributing to characteristics of the interprofessional social network. Communication networks and discussion networks were more commonly found within professional groups than between professional groups in both an emergency department and a renal ward (Creswick & Westbrook, 2007; Creswick et al., 2009). In surgical teams, registered nurses constituted the majority of core interdisciplinary team members (Anderson & Talsma, 2011). Such information can be used for health care teams to increase their communication, teamwork, and effectiveness. Especially in the current health care environment, there is a great need for multidisciplinary teamwork, efficient communication, and effective interpersonal interactions to share useful information for patient care (Creswick et al., 2009). Creating multidisciplinary teamwork within or across networks might be a challenge because people naturally cluster together with whom they are comfortable (Cunningham et al., 2012). Thus, it is important to understand the nature and dynamics of communication and teamwork in health care disciplines, and the current study findings can be used to create effective health care teams to promote their communication, collaboration, diffusion of new practice, and knowledge sharing (Barnett et al., 2012; Cunningham et al., 2012; West et al., 1999). This will contribute to patient safety and quality of care.

In terms of the relationship between social network and care process/outcomes, the evidence shows that several network figures are related to the adoption and diffusion of a hospital information system (Anderson & Jay, 1985a, 1985b) and health care use (Barnett et al., 2012). Regarding the communication network, the density and centrality of the communication network were related to positive patient outcomes (Effken et al., 2013). On the other hand, clustering and hierarchy of the communication network affected care outcomes adversely (Effken et al., 2013). Although all studied reviews were observational studies and not intervention studies, such findings can be used to change the network structure to improve patient safety outcomes and quality of care as well as retain more nurses with greater job satisfaction. Particularly, among health care professionals, hierarchical relationships were common (Creswick & Westbrook, 2007, 2010; Rangachari, 2008; Tighe et al., 2012), so it is important to understand that such hierarchical relationships are adversely related to patient outcomes. To improve patient safety and quality of care, it is recommended that health care provider teams need to avoid

clustering and hierarchy of the communication network (Effken et al., 2013).

As mentioned, relatively few studies examined the relationships between social network and care process/patient safety outcomes. To provide conclusive recommendations of social network features for health care providers to promote better patient safety and quality of care, future studies need to examine how the structural aspects of health professional networks can be leveraged to improve quality of care and patient safety outcomes. Given increased emphasis of health care providers' teamwork and communication among team members, it is critical to understand the social network among health care providers and use them for patient safety and quality of care as well as better outcomes for health care providers' teamwork.

Conclusion

In conclusion, this systematic review on the state of SNA in health care settings revealed a broad range of descriptive evidence. Current evidence reveals assessments of inefficiencies in health care teams. Major factors in the structure of health care networks include the characteristics of the health care professional, the characteristics of the patient, and the care setting. In addition, SNA has been used to describe associations with electronic health information system adoption, patient outcomes, and care coordination. However, the methodological quality of current studies reveals a risk for bias in the current state of the evidence. In the health care disciplines, communication and teamwork are critical for patient safety and quality of care. Thus, current study findings can be used to create effective health care teams to promote their communication, collaboration, diffusion of new practice, and knowledge sharing. Future study using enhanced sophistication in study design, analysis, teamwork and communication training interventions, and patient outcome testing are warranted.

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