

Health professional networks as a vector for improving healthcare quality and safety: a systematic review

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ABSTRACT

Background: While there is a considerable corpus of theoretical and empirical literature on networks within and outside of the health sector, multiple research questions are yet to be answered.

Objective: To conduct a systematic review of studies of professionals' network structures, identifying factors associated with network effectiveness and sustainability, particularly in relation to quality of care and patient safety.

Methods: The authors searched MEDLINE, CINAHL, EMBASE, Web of Science and Business Source Premier from January 1995 to December 2009.

Results: A majority of the 26 unique studies identified used social network analysis to examine structural relationships in networks: structural relationships within and between networks, health professionals and their social context, health collaboratives and partnerships, and knowledge sharing networks. Key aspects of networks explored were administrative and clinical exchanges, network performance, integration, stability and influences on the quality of healthcare. More recent studies show that cohesive and collaborative health professional networks can facilitate the coordination of care and contribute to improving quality and safety of care. Structural network vulnerabilities include cliques, professional and gender homophily, and over-reliance on central agencies or individuals.

Conclusions: Effective professional networks employ natural structural network features (eg, bridges, brokers, density, centrality, degrees of separation, social capital, trust) in producing collaboratively oriented healthcare. This requires efficient transmission of information and social and professional interaction within and across networks. For those using networks to improve care, recurring success factors are understanding your network's characteristics, attending to its functioning and investing time in facilitating its improvement. Despite this, there is no guarantee that time spent on networks will necessarily improve patient care.

BACKGROUND

Interest in networks as collaborating, professionalised structures continues to grow. As a post-bureaucratic form of organisation,¹ networks have gained increasing popularity for governments and policymakers. With a considerable corpus of literature on networks within and outside the health sector, it is timely to assess the current state of knowledge, particularly in relation to how the features of networks may be applied to improve quality and outcomes of care. 'Network' is a word used extensively in healthcare research and in health services delivery. It is used as a synonym for 'partnership', 'collaboration', 'alliance' and 'group', or more specifically to describe the relationships between people, groups or organisations.

A 'social network' is a 'set of people or groups of people, "actors" ... with some pattern of interactions or "ties" between them ... [eg,] friendships among a group of individuals, business relationships between companies'.² There is a long history of examining social networks through network analysis techniques, with researchers focusing on structural and relationship properties.^{3–5} Social network analysis (SNA) can be used to examine structural relationships and influence in networks, the way information travels in networks, diffusion of innovative ideas, tools or practices, and sustainability of networks. It is the structure of networks and how the structural properties affect behaviour that is informative, not simply the characteristics of the network members.^{6–7} Comprehensive reviews of the tools of SNA are provided by Knoke and Yang,⁸ Scott⁴ and Wasserman and Faust.⁵ The online

supplement (table S1) presents key SNA terms, along with their associated definitions, theories and propositions.

Work on the diffusion of medical innovations by Becker⁹ and Coleman *et al*¹⁰ has confirmed the importance of local peer influences or social networks. While several reviews of social and organisational networks exist in the non-health sector literature,^{11–13} this review focuses on the health sector, in particular on health professional networks. Drawing from a literature review of complex socio-technical systems, Braithwaite *et al*¹⁴ argued for exploitation of natural network characteristics to achieve safer, better healthcare. Similarly, Parchman *et al*¹⁵ contend that efforts to understand the delay in adoption of evidence-based guidelines have been hindered by an overreliance on the attributes, knowledge, decision-making, and actions of individual clinicians, and an under-recognition of the network of care within which they operate.

Despite considerable progress in understanding what networks are, how they are structured, how they operate, and how they develop, we still know little about their effectiveness and sustainability in the health sector or their contributions to quality of care and patient safety.¹⁶ For example, Provan and Milward¹⁷ note the scarcity of comparative network data that are tied to outcomes, citing work by Lehman *et al*¹⁸ and Provan and Milward,¹⁹ while Provan and Kenis²⁰ highlight the critical role of network governance and its impact on network effectiveness. This review examines the empirical research on the structure of networks of health professionals, with regard to the effectiveness and sustainability of networks, especially in relation to quality of care and patient safety.

METHODS

The systematic review was part of a broader review of the literature on social-professional networks of health professionals from 1995 to 2009.²¹ This period was selected because most of the empirical work on health professional networks has been published since 1995, spurred on by advances in computing capacity and enabled through the development of SNA software. The search strategy (figure 1) obtained a subset of 26 articles bearing on network structure. The literature search was conducted between September and December 2009 using five electronic databases: MEDLINE, CINAHL, EMBASE, Web of Science (Science Citation Index, Social Science Citation Index, Arts & Humanities Citation Index) and Business Source Premier (Management & Business). Trial searches were undertaken with a number of additional electronic databases (LISA, Scopus, ABI-Inform-Global, IBSS, EconLit), however these did not yield additional papers and were not included in the

search. We did not include the 'grey literature' as it did not meet the quality criteria of being peer reviewed and published in scholarly journals.

Following a preliminary review of terms in the literature, and of the MeSH database definitions of terms, key search terms were selected by the researchers to identify published research literature on social networks of health professionals (see online supplement, table S2). The key search term utilised was 'social network' for the initial search yielding 14 607 articles. As the intent was to explore the literature relating only to social networks of health professionals, additional terms in this table were used to refine the search. To narrow the review to relevant material, a two-stage approach was used so that the articles generated from the first stage, the initial 'social network' search, were then examined in combination with each of the subsequent terms, in separate searches.

Search articles were reviewed to remove duplicates and incomplete references, yielding 1560 articles. The titles and abstracts were examined independently by two reviewers using inclusion and exclusion criteria. Under inclusion criteria, research had to focus in some depth on one or more aspects of networks of practising health professionals, or health agencies, particularly with relevance to quality of care and sustainability; that is, mere mention of the term 'network' was not sufficient. Other inclusion criteria included empirical research, peer reviewed, English language, scholarly journals, human and abstract and full text available. Exclusion criteria included articles on social networks of patients, clients or caregivers; health service networks (with no relevance to health professional practice relationships); non-health professionals (except for those working in the health system, health administrators or health policy makers); internet social networking; student-education processes; academic professionals or research scientists; infection control or epidemiological networks; bio-networks and neural networks; and e-health systems and software not relating to health professional practice.

This yielded 66 articles, obtained in full text for independent review by the two reviewers. By drawing on published checklists,^{22–25} quality was assessed according to the following: whether there was a clear and systematic description of the aim of the study, participants, sampling strategy, data collection and analysis methods, results of the study, relationship between the researchers and the participants, context and setting of the study, strengths and weaknesses, and implications of the study. (The study quality assessment criteria and ratings, the inclusion criteria and review process are set out in the online supplement: table S3 and boxes S1 and S2). Studies were excluded only after discussion among at least two reviewers, who assessed and agreed on the inclusion and quality rating of the studies. From this

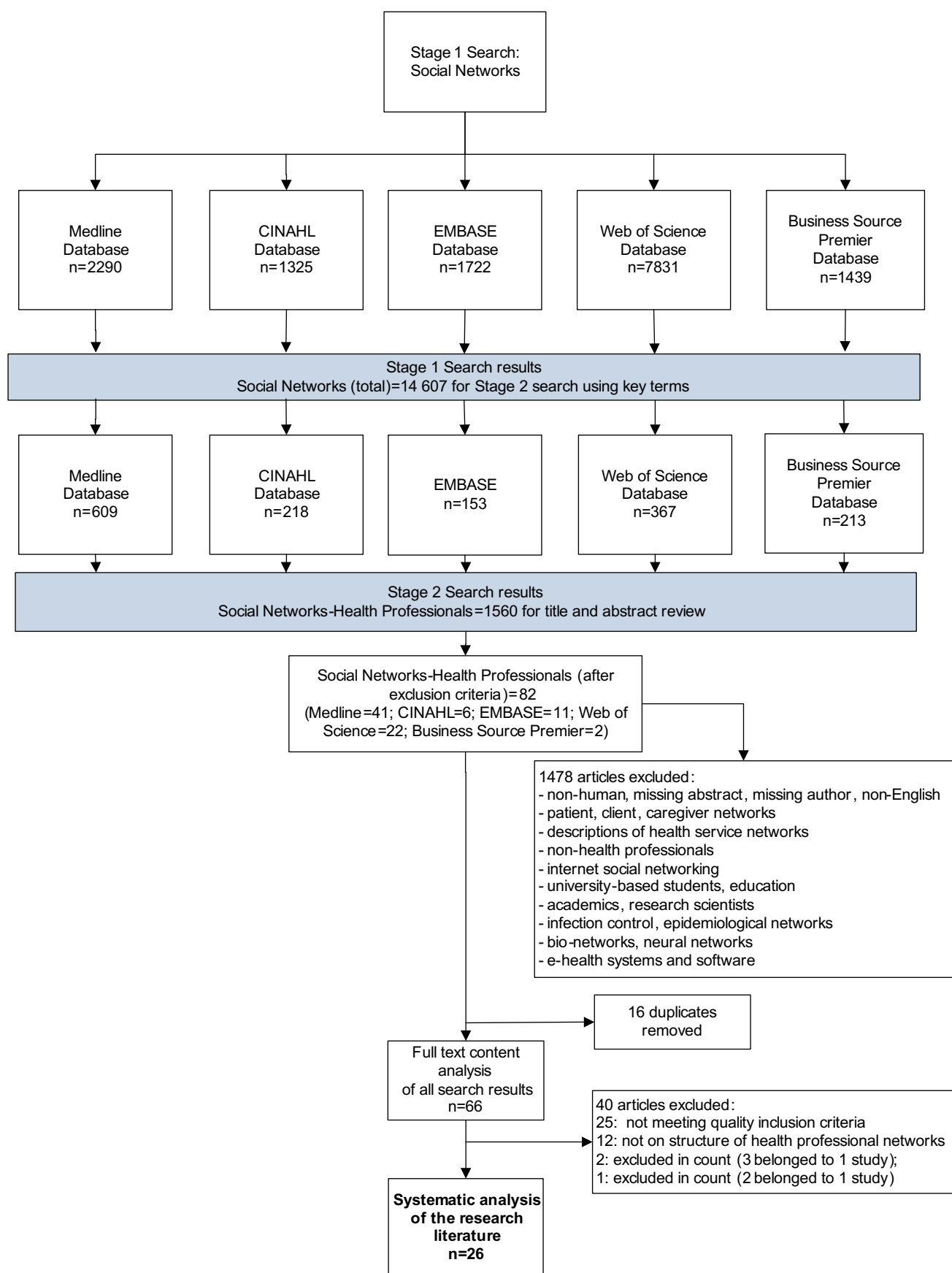


Figure 1 Flowchart of systematic review.

sample we derived 26 articles with a focus on the structure of networks of health professionals, which met all the inclusion criteria and quality assessment criteria, and which were peer reviewed, empirical articles deploying recognised, clearly described research methods. Summary descriptive data from these studies were abstracted by one author (FCC) using a standard form to compile a tabular presentation of the study participants and setting, objective, design and method, and findings. All authors reviewed this documentation for accuracy and completeness. Full information was available within the articles reviewed without the need to contact study authors.

RESULTS

Overview of studies

The online appendix (table A) presents an overview of the 26 studies, including details of the study objective, participants, study dates, study context and findings. The online appendix (table B) also presents the research design and methodology of the studies, including a quality rating for each study, the data collection methods, sample size and response rate, and the type and level of analysis. **Table 1** summarises the key study characteristics and **table 2** presents the overall key structural findings relating to health network quality and safety. More than half (14) of the studies were published between 2004 and 2009. Half were undertaken in the USA, with hospital settings (11) representing the largest proportion. Of the 24 studies directed at health professionals, seven focused on multidisciplinary groups of clinicians, with others primarily studying single health professions (nine) or single health domain professionals (six). Four studies researched healthcare collaboratives or partnerships.

With respect to quality and safety, the studies have relevance to five of the six quality improvement dimensions identified by the Institute of Medicine,⁵³ as indicated in the online appendix (table A, column 2): safe,^{30 31 34 35 41–43 49} effective,^{26 28 33 38 45 47} patient-centred,⁵⁴ efficient,^{35 39 48 50–52} and equitable.³² Timeliness was not addressed. Other aspects addressed by review studies with relevance to quality included culture,⁵⁵ interdisciplinary teamwork,^{29 36} service integration^{44 46 47} and stability,^{33 34 47} and diffusion of new practices.^{27 37 40}

Research design and analytical approach

As detailed in the online appendix (tables A and B), two studies used ethnography, while the 24 quantitative studies included case studies, multi-case studies, and cross-sectional studies. Principal data collection methods included surveys (23 studies), interviews (4), ethnographic observation (2) and archival data collection (2).

Table 1 Characteristics of studies

Characteristic	Number of studies	%
Year		
1995–1999	7	27
2000–2004	5	19
2005–2009	14	54
Country		
USA	13	50
Australia	4	15
Canada	3	12
UK	2	7
Germany	1	4
Italy	1	4
Sweden	1	4
Taiwan	1	4
Setting		
Hospital based	11	42
Community health based	7	27
Primary and secondary care health professionals	4	15
Healthcare collaboratives	2	8
Aged care	1	4
Multi-disciplinary research institute	1	4
Type of health professional		
Multidisciplinary	7	29
Mental health professionals	5	21
Health service managers or administrative staff	4	17
Nurses	3	13
Medical practitioners	2	8
Varied health professionals	2	8
Dementia care professionals	1	4
Study design		
Multi-case study	11	42
Case study	8	31
Cross-sectional study	5	19
Ethnographic case study	2	8
Level of analysis		
Actors and team	3	12
Actors and organisation (or network)	14	54
Organisation (or network)	8	31
Actors, organisation and external network	1	4
Data collection		
Survey	23	88
Ethnography	2	8
Archival data	2	8

Most (19) used SNA to analyse data, with one study adding survival analysis, three studies using multiple regression, and two using other social science analyses. While 11 of the SNA studies had high response rates in the 90–100% range, the survey response rates varied from 100% or whole network samples^{39 47} to a low of 20%.³⁸ The online appendix (table B, column 8) identifies the key aspects of network structure examined in each SNA study.

Table 2 Key structural network findings for health network quality and safety

Network feature	Key structural findings for health network quality and safety	Studies
Brokerage	Important in bridging connections and obviating 'structural holes' in hospitals Good coding performance is associated with a knowledge sharing network structure rich in brokerage and hierarchy, rather than density	Heng <i>et al</i> (2005), ²⁶ West and Barron (2005), ²⁷ Rangachari (2008) ²⁸
Centrality	Centrality of key organisations or actors in a network is important, and can be a strength or potential vulnerability for network sustainability Directors of nursing are more central in their networks than clinical directors of medicine and their networks are more hierarchical—hence better adapted to gathering and disseminating information The higher the centrality of the hospital in its network, the better the hospital performance	Cott (1997), ²⁹ Creswick and Westbrook (2007), ³⁰ Creswick <i>et al</i> (2009), ³¹ Gold <i>et al</i> (2008), ³² Lewis <i>et al</i> (2008), ³³ Mendel <i>et al</i> (2009), ³⁴ Mossholder <i>et al</i> (2005), ³⁵ Webster <i>et al</i> (1999), ³⁶ West and Barron (2005), ²⁷ West <i>et al</i> (1999), ³⁷ Peng <i>et al</i> (2006) ³⁸
Degrees of separation	Analysis of 'degrees of separation' can show the level of connectivity in a professional network	Creswick <i>et al</i> (2009) ³¹
Density	The denser the GP network the lower the variation in performance Clinical directors of medicine are embedded in more densely connected networks (cliques), than directors of nursing, and can be stronger instruments for changing, or resisting changes, in clinical behaviour. Networks of directors of nursing have lower density, with advantages in accessing information	Fattore <i>et al</i> (2009), ³⁹ West <i>et al</i> (1999), ³⁷ West and Barron (2005) ²⁷
Diffusion	Ideological tension can block the spread of knowledge and new work practices within the professional network Gaps in the network of informal ties will impede the dissemination of information and the spread of social influence between nurse executives and physician leaders, while non-clinical managers have a brokerage role	Ormrod <i>et al</i> (2007), ⁴⁰ West and Barron (2005) ²⁷
Homophily	People seek advice, or influence or discuss important professional matters with those similar to themselves (profession, gender, age, seniority), with implications for communication exchanges Physician leaders have more extreme homophily than senior nurses	Chase (1995), ⁴¹ Cott (1997), ²⁹ Creswick and Westbrook (2007), ³⁰ Creswick <i>et al</i> (2009), ³¹ MacPhee (2000), ⁴² MacPhee and Scott (2002), ⁴³ Webster <i>et al</i> (1999), ³⁶ West and Barron (2005), ²⁷ West <i>et al</i> (1999) ³⁷
Hierarchy	A large number of people in the network seek information from particular individuals For health professional teams other than medicine, collaboration on problem-solving and decision-making is limited to higher status professionals Nursing networks are more hierarchical than medical networks	Creswick and Westbrook (2007), ³⁰ Cott (1997), ²⁹ West <i>et al</i> (1999) ³⁷
Integration and cliques	Relationships between groups of agencies, services or providers (cliques) in a network may be more important than the relationship between all agencies in the network SNA can identify agencies and actors who are not well linked in the network	Calloway <i>et al</i> (1999), ⁴⁴ Lemieux-Charles <i>et al</i> (2005), ⁴⁵ Milward and Provan (1998), ⁴⁶ West <i>et al</i> (1999) ³⁷
Multiplexity	Employees forming a greater number of ties with co-workers are more embedded and have lower turnover	Mossholder <i>et al</i> (2005) ³⁵
Network roles	Individual roles in networks are important for communication and information dissemination: 'broker' and 'bridging' roles, 'cliques', 'isolates'	Gold <i>et al</i> (2008), ³² Heng <i>et al</i> (2005), ²⁶ Mendel <i>et al</i> (2009), ³⁴ Lewis <i>et al</i> (2008), ³³ West <i>et al</i> (1999), ³⁷ West and Barron (2005) ²⁷

Continued

Table 2 Continued

Network feature	Key structural findings for health network quality and safety	Studies
Network stability	Network stability is related to network effectiveness, and can moderate the impact of resources Longitudinal SNA can measure network expansion, with decreased fragmentation increasing potential information flow	Milward and Provan (2003), ⁴⁷ Mendel <i>et al</i> (2009) ³⁴
Reciprocity	Reciprocity of ties shows whether there is a hierarchical (low reciprocity) or horizontal (high reciprocity) structure in the professional network	Creswick and Westbrook (2007), ³⁰ Creswick <i>et al</i> (2009) ³¹
Social capital	Organisational social capital, in addition to professional experience and workload, can predict overall job satisfaction Social influence of peer professionals has a greater impact than social capital on health professional performance	Ommen <i>et al</i> (2009), ⁴⁸ Fattore <i>et al</i> (2009) ³⁹
Social climate	Positive social climate protects nurses against burnout Professional and social networks and support do not mitigate against work stress of chief manager nurses or physician clinical directors	Garrett and McDaniel (2001), ⁴⁹ Lindholm (2006), ⁵⁰ Lindholm <i>et al</i> (2003), ⁵¹ Lindholm <i>et al</i> (2004) ⁵²

Based on our quality assessment criteria (see online supplement, table S3), the quality ratings of the studies are provided in the online appendix (table B). Fourteen studies (54%) were assessed as meeting all of the quality assessment criteria relevant to their study design. Ten studies (39%) met almost all of the criteria, and those criteria that were not fulfilled were thought unlikely to alter the conclusions of the study. In two studies (7%), some of the criteria were fulfilled, and those criteria that were not fulfilled were thought unlikely to alter the conclusions of the study. We did not include studies that met few or no quality assessment criteria.

The level of analysis is a key area of interest in network studies. There are three principal levels: the actor/s level, the network (or organisation) level and the inter-network (or inter-organisation) level. Seventeen studies were directed at two levels, the actors and the network (three looked at the actors and team), eight studies examined networks and one examined all three levels. Four main areas of structural relationships were studied: structural relationships within and between organisations; health professionals and social context; structure of quality collaboratives and healthcare partnerships; and structure in knowledge sharing networks. Table 2 summarises the key network features examined by individual studies, and identifies the substantive structural findings for health network quality and safety, in relation to those network features.

Structural relationships within and between organisations

Six studies examined structural relationships within and between networked organisations, including two of dementia provider networks, three of mental health provider networks (one comparing rural and urban

relationships) and one of a hospital network. Carpentier *et al*⁵⁴ used comparative case studies of seven organisations to examine relationships between the networks providing assistance to community patients with early-stage dementia in Montreal, Canada. The three interaction levels (interactions between practitioners and caregivers, internal structures and linkages between groups) were found to determine the quality of the practitioner–caregiver interface. Another Canadian case study on dementia care⁴⁵ evaluated the effectiveness of four community-based dementia care networks in Ontario. SNA identified patterns of administrative and clinical exchanges among networked agencies. Exchanges between groups of agencies (cliques) within each of the four networks were more important than those between individual agencies within each network.

In seminal work examining network structure and effectiveness in the health sector, Milward and Provan^{46 47} used SNA to examine structural relationships in networks of provider organisations in two studies. The 1998 research included four city community mental health networks and one youth substance-abuse prevention network. Each of the four mental health networks was well integrated, based on two measures – organisational links and cooperative links. With the substance-abuse prevention network, SNA helped to identify agencies not well linked to the system. Milward and Provan⁴⁷ then used SNA on the results of the initial research, along with a 4-year study of one of the four networks, to evaluate collaboration and contracting strategies. The relationship between network structure and effectiveness was mediated by the context within which services were provided, with resource munificence and network stability identified as the two contextual

variables. In the initial study, network stability moderated the impact of resources. In the 2003 study, an effective network was one with enough stability to maintain its ability to manage a set of jointly produced services.

Another study in a US mental healthcare setting⁴⁴ used SNA to compare two rural and four urban care systems for people with severe mental disorders (SMDs). Both rural sites had numerous coordination linkages between the two types of provider groups (SMD and other service providers) for service planning and delivery. Density scores revealed the extent of service dependency when providers coordinated care to people with SMD in rural sites compared with urban sites. Service relationships among all specialised mental health providers were more likely to occur in rural than urban areas.

A study of chief executive officers in all accredited Taiwanese hospitals³⁸ examined the impact of hospital resources, network resources and centrality on hospital performance. Hospital resources and centrality independently affected performance, whereas network resources did not. For that setting, the authors conclude that a hospital should improve performance by exploiting its in-house resources rather than obtaining network resources externally, and should occupy a central position to create a structural niche.

Health professionals and social context

Half of the studies (13) examined health professionals and social context, including six on work climate. Chase⁴¹ used ethnography in two intensive care units (ICUs) in a US teaching hospital to analyse structure and communication patterns relating to the social context in which the process of critical care clinical judgement occurred from the nurse's perspective. With multiple clinicians involved in ICU patient-care decision-making, parallel hierarchies of nurses and of doctors allowed for checks on judgement both within and across professional lines. Also, rituals (nursing reports, physician rounds, flow sheet use) provided a context to check judgement processes.

Lurie *et al*⁵⁵ applied SNA to three settings in one US clinical institution: team function in the ICU, the interdisciplinary composition of advisory committees, and relationships between key function directors. Researchers used SNA to compare teams on aspects of their clinical team functioning, and to show the degree of inter-disciplinarity of various clinical departments on the advisory committees. SNA identified potential problem areas with gaps in knowledge of functional roles among academic departments.

SNA was employed by Cott²⁹ to describe the structure of three multi-disciplinary, long-term care teams in a Canadian geriatric care facility. Effects of teamwork in

sharing decision-making were limited to a group of higher status health professionals other than medicine, with the clearly defined hierarchy remaining for lower status sub-disciplines. Garrett and McDaniel⁴⁹ conducted a cross-sectional study of five units in a US hospital to explore the relationships of environmental uncertainty, nurse characteristics and perceived work climate with professional burnout. Environmental uncertainty and perceptions of social-work climate were associated with burnout, yet findings suggested a positive social network climate could shield workers from the negative effects of crisis.

Mossholder *et al*³⁵ applied SNA and survival analysis to study healthcare employees in a large public US medical centre, examining whether structural, attitudinal and behavioural variables of a relational nature were predictive of employee turnover. Two variables, network centrality and interpersonal citizenship behaviour, predicted turnover with effects above and beyond the effects of job satisfaction. Workers forming more ties with coworkers (network centrality) became more embedded and had lower turnover, and higher interpersonal citizenship behaviour resulted in lower turnover.

A study of physicians in four German hospitals analysed the relationship between overall job satisfaction of physicians and social capital in the hospitals.⁴⁸ Job satisfaction was significantly associated with professional experience, and with lower workloads. The social capital of an organisation was a significant predictor of overall job satisfaction of physicians. In a similar research area, Swedish studies^{50–52} investigated whether psychosocial work conditions, professional network, job support, social network and support, sick leave and salary were associated with work stress in nurses in chief manager positions and physicians in clinical director positions. For both roles, a significant association was found between exposure to high job demands and a high level of work stress. Here, available psychosocial resources, inside and outside work, did not balance the experienced work stress in nurse managers and clinical directors exposed to high work demands.

The work of nurses with flexible and traditional schedules was compared in a US case study in an urban paediatric acute-care hospital.⁴² Applying SNA to examine the types of social networks used by both groups of nurses and to compare their workplace socialisation, no significant differences were found in the nurses' social network composition. However, traditional nurses used significantly more peer members for different types of emotional support. MacPhee and Scott⁴³ also applied SNA to examine workplace social support networks of rural hospital nurses, compared with the urban nurse networks. Rural nurses' networks

were predominantly peer based, but managers provided significant functional supports, with rural nurses expecting more guidance from management than urban nurses.

Ethnography was employed by Ormrod *et al*⁴⁰ in three UK NHS mental health clinics to examine how organisational practices were spread within networks of practice. Professional networks within psychiatry were found not to spread particular work practices equally to psychiatrists and their associated multi-disciplinary teams at two new sites. This was largely due to ideological differences in psychiatric practice approaches and differences in founder influence.

Webster *et al*⁸⁶ used SNA data on advice and social relations, to examine differences in eight mental health case-management teams in a Californian (USA) county mental health system. Male supervisors were substantially more central for 'instrumental' (advice) relations than female supervisors, displaying an autocratic leadership style. Male supervised teams were more centralised than female supervised teams. For the 'social' relations, male team supervisors were more central than female supervisors. Teams with female supervisors were more centralised than those with male supervisors, yet the female leaders were not the most central team member, showing a democratic leadership style.

Significant research on the professional social networks of clinical directors of medicine and directors of nursing in UK hospitals was undertaken by West *et al*.³⁷ Directors of nursing were more central in their networks than clinical directors of medicine, and their networks were more hierarchical. The networks of directors of nursing had lower density (having advantages in terms of access to information) than the clinical directors of medicine who tended to be embedded in much more densely connected networks (cliques). Doctors' networks were more egalitarian and decentralised than nurses' networks, hence change processes for the doctors need to involve group processes, rather than simply convincing individuals of the need to change.

In West and Barron's subsequent research,²⁷ both directors of nursing and clinical directors of medicine discussed 'important professional matters' with others similar to themselves in terms of profession, gender, age, and seniority (homophily), with doctors being more extreme in this regard. Managers (non-clinically qualified) occupied a powerful brokerage role for both nurses and doctors, whereas nurses and doctors were rarely on each other's networks. Nursing and medicine had quite different social structures. With few informal ties between the two professions, information was unlikely to be spread between professions by informal sources.

Structure of quality collaboratives and healthcare partnerships

Four studies show the application of SNA in examining the structure and sustainability of collaboratives and partnerships. Gold *et al*⁸² applied SNA to research relationships (structure and processes) among organisations participating in a large-scale, public-private, quality collaboration among major US health plans to reduce racial and ethnic disparities in healthcare. Sponsors and support organisations, along with a few of the health plans, formed the 'glue' holding the collaboration together. With limited communication among health plans, if the collaboration ended without greater communication among the non-core organisations, the absence of the core would leave a very sparse network. Gold *et al* advised collaborative sponsors to consider both short-term and long-term goals and whether they can be pursued if a collaborative ends.

Mendel *et al*⁸⁴ used SNA to explore the numbers and types of inter-organisational partnerships within the US patient safety domain, the changes over time in these networks, and their potential for disseminating patient safety knowledge and practices. Between 2004 and 2006, partnerships grew in all activity domains, particularly dissemination and tools development, signifying growing strength in the capacity to disseminate and implement patient safety advancements. Fragmentation of the overall partnership network decreased, and potential for information flow increased. However, network centralisation increased, suggesting vulnerability to partnership failure if key participants disengaged.

SNA was applied by Lewis *et al*⁸³ in a longitudinal analysis of network structure, dynamics and sustainability in primary care partnerships in Victoria, Australia at three time points between 2002 and 2005. Although network structures changed over the 3 years, there was the continuing centrality of the independent staff employed to manage the partnerships, with their crucial role in holding partnerships together. These partnerships required long-term support, not just start-up funding.

To study whether collaboration initiatives by a local health authority in Italy between 2001 and 2004 had any effect on individual and district-level general practitioner (GP) performance on drug expenditure targets, Fattore *et al*⁸⁹ used SNA. In terms of the GP's ability to meet expenditure targets, the social influence mechanism (the performance of peers to whom the GP was directly connected) was more relevant than the social capital mechanism (the centrality of the GP in the network). While collaborative arrangements induced more homogeneous behaviour among GPs, they did not necessarily improve the ability of GPs to meet local health authority objectives.

Structure in knowledge sharing networks

The importance of homophilous behaviour was identified by Creswick and Westbrook³⁰ who examined how a network of staff in an Australian hospital renal ward sought medication advice. Most communication occurred within professional groups. Similarly, a study of a network of staff in an Australian hospital emergency department by Creswick *et al*³¹ found that, when seeking advice, individuals were more closely connected to colleagues in their own professional groups. Heng *et al*²⁶ used SNA to explore the brokerage role of facilities management in an Australian hospital. Facilities managers actively bridged information and knowledge across different functions, filling structural holes within a communication network structure and being positioned to identify inter-disciplinary opportunities.

Although various studies discussed above identified features of network structure associated with better performance, Rangachari provided one of the few to link network structure with quality outcomes.²⁸ This research in four large US teaching hospitals used SNA to explore the relationship between the organisational knowledge sharing structure related to quality, and hospital coding performance related to quality. Good-coding performance was associated with a knowledge sharing network structure rich in brokerage and hierarchy (with senior leaders coordinating knowledge exchange related to quality and connecting the organisation with the external environment), rather than density (with everyone connected to everyone else).

DISCUSSION

This review examined the empirical research on the structure of networks of health professionals, with regard to the effectiveness and sustainability of networks, especially in relation to quality of care and patient safety. There is a convergence of many networks, independent of their age, function and scope, to similar architectures. This has allowed researchers from different disciplines to embrace network theory as a common paradigm.⁵⁶ Consistent with this theory, a number of the reviewed studies demonstrate the link between features of network structure and outcomes. Quality-related performance is associated with a knowledge sharing network structure rich in brokerage and hierarchy, rather than density.²⁸ Social influence in a network is positively related to physician performance,³⁹ social capital predicts overall job satisfaction,⁴⁸ positive social climate protects employees against burnout,⁴⁹ and employees with more co-worker ties have lower organisational turnover.³⁵

The evidence demonstrates that creating cohesive, collaborative networks (of professionals or agencies) can

pay dividends in coordinating care and attending to quality and safety issues and agendas.^{28 32 34 39 46 47} The presence of key players, often in management or leadership roles, who act as connectors to transmit information, bridge disparate groups, liaise across parts of networks and enable social and professional interaction is vital.^{26 27 32–34} They go by many names including mavens, connectors and bridges. In essence, they can facilitate communication and trust.²⁷ However, the centrality of key players holding a network together can also be a vulnerability of such networks if they are relied on excessively and then leave, change roles or become marginalised.^{32 34}

We have known for a long time that people naturally cluster together with those with whom they are comfortable: network theorists and sociologists call this homophily, and most people know this phenomenon as ‘birds of a feather flock together’.^{29–31} Creating multi-disciplinary or interprofessional teamwork within and across networks is thus a challenge. To address this challenge, active bridge building between subgroups across commonly occurring organisational divides (professions, genders and generations) is very important in creating larger, more resilient professional networks.^{26 27 36} Strategies for quality improvement must address these factors, and the different characteristics of disciplinary networks (eg, nursing and medicine).²⁷

As summarised in [table 2](#), the characteristics of networks are important in facilitating greater levels of quality of care and patient safety. How far apart individuals are, for example, their degrees of separation, how central the key actors are, how intense the network relationships are, how dense the network is, how hierarchical relationships are structured and how stable the network is and the actors within it are all factors that will determine how well functioning the network will be and how well the actions of interacting agents will cohere to provide services. The received wisdom from various studies seems to be that being in an effective network which encourages communication and facilitates trust helps people feel good about their relationships, and to reciprocate positively with others to develop social capital. Positively functioning networks are likely to contribute more broadly to an effective organisational culture and climate.^{49–52 57} In this respect, networks can represent not just the social glue of professional interaction but the sociological building blocks of effective organisations.

Finally, we should ask what is missing from the research evidence we have uncovered and discussed. Although a third of the studies link network structure with evidence of outcomes,^{28 35 38 39 47–50} most of the research examines only the structural features of health professional networks. Using multi-method approaches,

and exploiting advances in SNA,⁵⁸ further well designed research should examine the relationships between professionals' network structures and health outcomes in a range of different care settings, and how the structural aspects of health professional networks can be leveraged to improve quality of care and patient outcomes. As to limitations, like all systematic reviews, this review is bounded by its scope and the range and quality of the research we have been able to uncover. The grey literature was not included as it did not meet study inclusion criteria. It is challenging to draw together the lessons to be learnt from disparate studies, even those that share a common focus and methodology.

CONCLUSION

On the basis of this review, for those participating in or supporting networks, the lessons are threefold. First, understanding the structure and characteristics of professional networks is vital, and second, it is important to attend to how they function. This leads to a third lesson: it may be time well spent, depending on local conditions, to nurture professional networks, and invest the time to facilitate their contributions to care. For example, recent work by Meltzer *et al*⁵⁹ demonstrates how SNA can assist in the design of effective quality improvement teams. The wellbeing of the organisation, the quality of services provided, and the collective efforts to deliver safe care to patients are likely to depend on such efforts. Spending time enabling networks is quite likely to be a useful pursuit for those intent on developing sustainable and well functioning organisations. However, this is not guaranteed and even if progress can be made, it is likely to be time consuming with no assurance that the investment in energy and effort will realise improved systems, cultures and delivery systems. Our review has shown, nevertheless, that existing research provides a foundation for a potentially fruitful yet underexplored research agenda in ascertaining the worth of networks in improving clinical care.

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All authors contributed to writing the manuscript, and all authors have agreed on the final version of the manuscript.

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Appendix Table A: Reviewed studies: objective, participants, study dates, context and findings

Study (No.=26)/ [Database]	Objective [Quality Area]	Participants, Study Date	Context	Findings
Calloway et al., 1999[51] [Medline]	Compare rural service systems and urban systems in coordinating and structuring services. [integration]	Participants: mental health professionals - key informants of each area's public mental health, developmental disabilities and substance abuse programs. When: 1994 (rural); 1989,1991 (urban)	USA; 2 rural mental health networks: North Carolina, 4 urban mental health networks: Cincinnati, Toledo and Columbus, Ohio, and Baltimore, Maryland.	<ul style="list-style-type: none"> Continuum of care for people with severe mental disorder involved more specialised mental health providers in urban systems. Service relationships between all specialised mental health providers: more likely to occur in rural than urban areas.
Carpentier et al., 2008[41] [Web of Science]	Explore practitioners' perspectives to understand dynamics influencing relationships between the assistance networks for seniors. [patient-centred]	Participants: dementia care providers. When: 2003	Canada; Montreal; 7 dementia provider groups.	<ul style="list-style-type: none"> Players' profiles, internal structures and external links determined the quality of the practitioner-caregiver interface. Beneficial factors: heterogeneity of professional groups and establishment of contacts in early stages of dementia.
Chase, 1995[27] (29) [Cinahl]	Describe the social context in which the critical care clinical judgment in nursing occurs. [safe]	Participants: nurses, physicians. When: 1990	USA; north-eastern teaching hospital's 11-bed open heart ICU; a 10-bed general surgical ICU.	<ul style="list-style-type: none"> Nurses and physicians were organised in parallel hierarchies of nurses and physicians providing a system of multiple checks to prevent judgement lapses by either nurse or physician.
Cott, 1997[49] [Embase; Web of Science]	Describe the structure of multi-disciplinary long-term care teams' professional relationships. [interdisciplinary teamwork]	Participants: nursing, non-nursing professionals on five teams. When: 1995	Canada; multi-level geriatric care facility, metropolitan Toronto.	<ul style="list-style-type: none"> Any teamwork effects in increasing participation in decision-making by health professionals other than medicine were limited to a group of higher status professionals.

Study (No.=26) / [Database]	Objective [Quality Area]	Participants, Study Date	Context	Findings
Creswick & Westbrook, 2007[28] [Medline]	Examine how staff in a hospital renal ward seek medication advice. [safe]	Participants: doctors, nurses, allied health staff, administrative personnel. When: 2005	Australia; renal ward, metropolitan teaching hospital, Sydney.	<ul style="list-style-type: none"> There was a relatively low level of advice-seeking about medication-related decisions and tasks. Most communication occurred within professional groups. Medication advice was sought from several key individuals in the ward both within and across professional groups.
Creswick et al., 2009[29] [Medline]	Examine problem-solving, medication advice-seeking, and socialising professional networks. [safe]	Participants: doctors, nurses, allied health staff, administrative personnel. When: 2007	Australia; emergency department, metropolitan teaching hospital, Sydney.	<ul style="list-style-type: none"> In all 3 networks, individuals were more closely connected to colleagues in their own professional groups. The most densely connected network was the problem-solving network, then the medication advice network, followed by the socialising network.
Fattore et al., 2009[42] [Medline]	Study the impact of collaboration initiatives on drug expenditure in a Local Health Authority (LHA). [efficient]	Participants: GPs. When: 2001-2004	Italy; GPs in 2 districts, Empoli LHA, Tuscany region.	<ul style="list-style-type: none"> Centrality of GP in his or her network (social capital) had a small or insignificant effect on meeting expenditure targets. For social influence, there was a significant relationship between the performance of peers to whom the GP was connected and the GP's ability to meet the LHA's drug target. The higher density district showed lower variation in expenditures.
Garrett & McDaniel, 2001[30] [Medline; Web of Science]	Explore relationships in hospital-based units, of nurse characteristics, and perceptions of work climate with professional burnout. [safe]	Participants: nurses. When: ~2000	USA; full-time nurses, 493-bed acute care, mid-western hospital.	<ul style="list-style-type: none"> Perceived environmental uncertainty and social climate perceptions were associated with burnout. A positive social climate protected workers from negative effects of crisis.
Gold et al., 2008[47] [Medline]	Study relationships among organisations collaborating to reduce racial and ethnic disparities in health care. [equitable]	Participants: health plans, sponsor or support organisations. When: 2005-2006	USA; National Health Care Collaborative of large health plans.	<ul style="list-style-type: none"> SNA identified the central role of sponsor and primary support organisations and a few health plans in forming the network core, highlighting a potential weakness with centralised support in the network structure.

Study (No.=26) / [Database]	Objective [Quality Area]	Participants, Study Date	Context	Findings
Heng et al., 2005[35] [Medline]	Explore the brokerage role of hospital facilities managers. [effective]	Participants: Department heads of 15 different hospital departments (facilities managers). When: ~1999.	Australia; 700- bed tertiary referral metropolitan hospital, Sydney.	<ul style="list-style-type: none"> Structural holes measurement suggested the facilities management director's network position was strategic, bridging connections between other departments, obviating structural holes in the network communications.
Lemieux- Charles et al., 2005[36] [Embase]	Examine providers' perceptions of effectiveness of 4 community-based, not-for-profit dementia networks. [effective]	Participants: dementia care clinicians and managers. When: 1999 -2002.	Canada; 4 community-based dementia care networks, with 13 to 17 care provider organisations, Ontario.	<ul style="list-style-type: none"> The 4 networks differed in their perceptions of service-delivery effectiveness. Exchanges between groups of agencies (cliques) within each of the networks were more critical than those between agencies within each network.
Lewis et al., 2008[37] [Cinahl]	Examine primary care partnerships (PCPs) as a form of network governance; analyse their network structure, network dynamics, relationships and sustainability.	Participants: PCP project staff, partner agency staff, Department of Human Services (DHS) regional office staff. When: 2002-2005.	Australia; 2 PCPs, one urban and one rural, Victoria.	<ul style="list-style-type: none"> Although network structures changed over the study time, one constant was the continuing centrality of independent staff employed to manage the partnerships. Network dynamics of the partnerships exhibited resilience over time.
Lindholm, 2006[43] [Medline]; Lindholm et al., 2003[44] [Medline]; Lindholm et al., 2004[45] [Embase]	Study the association between psychosocial work conditions, professional network, job support, social network, support, sick leave and salary, and work stress. [efficient]	Participants: chief manager nurses, physician clinical directors. When: 2000-2002.	Sweden; chief manager nurses and physician clinical directors.	<ul style="list-style-type: none"> Nurse managers and clinical directors exposed to high job demands had a significantly high probability of a high level of work stress. Available psychosocial resources, did not balance their experienced work stress against high work demands.

Study (No.=26) / [Database]	Objective [Quality Area]	Participants, Study Date	Context	Findings
Lurie et al., 2009[48] [Medline]	Apply SNA to assessing medical centre culture. [culture]	Participants caregiver teams, research awardee advisory committees, and research leaders. When: 2007	USA; an ICU, advisory committees, and research leaders, in a medical centre.	<ul style="list-style-type: none"> SNA proved effective in measuring aspects of team function, interdisciplinarity of different clinical departments, and in exploring relationships between institutional leaders.
MacPhee, 2000[31] [Medline]	Contrast workplace socialisation and the types of social networks of nurses working flexible and traditional schedules. [safe]	Participants: nurse employees. When: ~1999	USA; 200-bed, metropolitan, paediatric, tertiary care facility, western United States.	<ul style="list-style-type: none"> No significant differences were found in composition of the nurses' social networks. Both nurse types belonged to peer-based networks including nurse managers.
MacPhee & Scott, 2002[32] [Embase; Web of Science]	Compare rural and urban nurses' workplace social support networks. [safe]	Participants: rural, urban hospital nurses. When: ~2001	USA; 10 rural hospitals in one region, and one urban hospital, Colorado.	<ul style="list-style-type: none"> Rural nurses used peers more than managers for all types of support. Rural and urban hospital nurses did not differ on structural aspects of support networks, nor for emotional support from peers or managers, however rural nurses expected more manager and peer guidance.
Mendel et al., 2009[33] [Web of Science]	Record the numbers and types of inter- organisational partnerships in the national patient safety domain, network dissemination capacity and changes longitudinally. [safe]	Participants: patient safety policy organisations. When: 2004, 2006.	USA; quality partnership networks.	<ul style="list-style-type: none"> The number of patient safety partnerships expanded between 2004 and 2006 in all activity domains, particularly dissemination and tools development. Network fragmentation decreased; potential for information flow increased.

Study (No.=26) / [Database]	Objective [Quality Area]	Participants, Study Date	Context	Findings
Milward & Provan, 1998[52] [Business Source Premier]	Examine the level of integration of 4 community mental health networks; measure structural ties in a substance-abuse prevention network. [integration]	Participants: mental health agencies; substance-abuse prevention network. When: 1991-1993.	USA; 4 city-based, community mental health networks, and a substance-abuse prevention network.	<ul style="list-style-type: none"> Each of the 4 mental health networks was well-integrated, based on two measures – organisational links and cooperative links, but in different ways. SNA helped identify substance-abuse network agencies that were not well-linked.
Milward & Provan, 2003[38] [Business Source Premier]	Examine 4 mental health networks and do a 4-year study of one of the 4 networks, to evaluate strategies of collaboration and contracting. [integration; stability]	Participants: mental health agencies. When: 1991-1993; 1996-1999.	USA; 4 city-based mental health networks, one with a managed care mental health network.	<ul style="list-style-type: none"> Resource munificence alone did not result in an effective network, nor did resource scarcity make a network ineffective. Network stability was the most critical variable in moderating resource impact, and was related to network effectiveness.
Mossholder et al., 2005[34] [Web of Science]	Relate structural, attitudinal and behavioural variables to employee turnover. [efficient]	Participants: health care employees. When: ~1999, ~2004	USA; large southern public medical centre.	<ul style="list-style-type: none"> Employees forming a greater number of ties with co-workers were more embedded, with lower turnover. Higher levels of interpersonal citizenship behaviour resulted in lower turnover.
Ommen et al., 2009[46] [Medline; Web of Science]	Analyse the relationship between job satisfaction of physicians and social capital in hospitals. [efficient]	Participants: physicians. When: 2002	Germany; 4 hospitals.	<ul style="list-style-type: none"> Organisational social capital, in addition to professional experience and workload, significantly predicted overall job satisfaction.
Ormrod et al., 2007[53] [Business Source Premier]	Examine how diffusion of new work practices within a network is affected by organisational power. [diffusion]	Participants: psychiatrists and their multidisciplinary teams. When: ~2002-2006	UK; 3 NHS mental health clinics.	<ul style="list-style-type: none"> Professional networks within psychiatry did not spread the initial clinic's therapeutic practices equally to two new sites.

Study (No.=26) / [Database]	Objective [Quality Area]	Participants, Study Date	Context	Findings
Peng et al., 2006[39] <i>[Web of Science]</i>	Examine the impact of hospital resources, network resources and centrality on hospital performance. <i>[effective]</i>	Participants: hospitals. When: 2001	Taiwan; accreditation-qualified hospitals	<ul style="list-style-type: none"> Hospital resources and centrality independently affected performance, whereas network resources did not. The higher the centrality, the better hospital performance.
Rangachari, 2008[40] <i>[Embase]</i>	Examine relationships between organisational knowledge sharing and hospital coding performance. <i>[effective]</i>	Participants: quality staff, medical staff and coding administrators. When: ~2006	USA; 4 Manhattan hospitals, New York.	<ul style="list-style-type: none"> Good-coding performance was systematically associated with a knowledge sharing network structure rich in brokerage and hierarchy, rather than density.
Webster et al., 1999[50] <i>[Medline]</i>	Examine differences in leadership styles. <i>[interdisciplinary teamwork]</i>	Participants: mental health professionals. When: ~1998	USA; 8 mental health case management teams, California.	<ul style="list-style-type: none"> Male leaders were the most central team members for instrumental and expressive relations – an autocratic leadership style. Female leaders had a democratic leadership style.
West et al., 1999[55] <i>[Medline]</i> ; West & Barron, 2005[54] <i>[Medline]</i>	Describe social and geographical boundaries of networks of senior nurse executives and physician leaders and managers. <i>[diffusion]</i>	Participants: nursing directors; medical directors. When: ~1998.	UK; NHS doctors and nurses in hospitals, England.	<ul style="list-style-type: none"> Both groups discussed 'important professional matters' with those similar to themselves (profession, gender, age, seniority), with physicians being the more extreme. Administrative managers held a strong 'brokerage' role. Directors of nursing were more central to their networks than medical directors, with more hierarchical networks. Medical directors were embedded in tightly knit groups (cliques).

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Appendix Table B: Research design and methodology of studies

Study	Study Design/ Quality	Methodology							
		Survey	Interview	Observation	Document Analysis or Archival Data	Sample size/ (response rate)	Social Network Analysis	Level of Analysis	Other Analysis
Calloway et al., 1999[51]	comparative case studies +++	√ (interview)	-	-	-	325 agencies (100%)	√ structure connections	networks	sociometric analysis
Carpentier et al., 2008[41]	comparative case studies +	√ (interview)	-	-	√	21 staff (95%)	√ connections	actor, organisation, inter-institutional	content analysis: NVivo
Chase, 1995[27]	ethnographic study ++	-	√	√	√	97 nurses (31% observed)	-	actors organisation	-
Cott, 1997[49]	case study ++	√ (self-administered)	-	-	-	153 health workers (60%)	√ structure homogeneity	actors, team	-
Creswick & Westbrook, 2007[28]	case study +++	√ (self-administered)	-	-	-	47 renal ward staff (96%)	√ connections homogeneity	actors, network	-
Creswick et al., 2009[29]	case study +++	√ (self-administered)	-	-	-	109 emergency department staff (94%)	√ connections homogeneity density	actors, network	-
Fattore et al., 2009[42]	comparative case study +++	-	-	-	archival data	92 GPs, 2001, 157 GPs, 2004 (100%)	√ social capital social influence density	actors, networks	multiple regression: OLS

Study	Study Design / Quality	Methodology							
		Survey	Interview	Observation	Document Analysis or Archival Data	Sample Size/ (response rate)	Social Network Analysis	Level of Analysis	Other Analysis
Garrett & McDaniel, 2001[30]	cross-sectional study +	√ (self-administered)	-	-	-	287 nurses (26%)	-	actors, organisation	multiple regression
Gold et al., 2008[47]	cross-sectional study +++	√ (mailed)	√	-	-	9 health plans, 6 support organisations (100%)	√ connections centrality	network (inter-organisation)	-
Heng et al., 2005[35]	case study ++	√	-	-	-	15 hospital managers (100%)	√ brokerage structural holes	actors, network	-
Lemieux-Charles et al., 2005[36]	multi-case study +++	√	-	-	√	1 clinician, 1 manager: each of 60 organisations (100%)	√ connections cliques	networks (inter-agency)	-
Lewis et al., 2008[37]	comparative case study +++	√ (3 annual interviews)	-	-	-	96 urban primary care, 98 rural (100%)	√ structure centrality stability	networks	-
Lindholm, 2006[43]; Lindholm et al., 2003[44]; Lindholm et al., 2004[45]	cross-sectional study +++	√ (mailed)	-	-	-	322 chief manager nurses (77%) 373 physician clinical directors (73%)	-	actors, network	odds ratios
Lurie et al., 2009[48]	case study ++	√	-	-	archival data	18 (ICU teams), 53 researchers, 157 committee members, 12 directors (100%)	√ connections	actors, networks	-

Study	Study Design / Quality	Methodology							
		Survey	Interview	Observation	Document Analysis or Archival Data	Sample Size/ (response rate)	Social Network Analysis	Level of Analysis	Other Analysis
MacPhee, 2000[31]	comparative case study ++	√	-	-	-	300 traditional nurses (40%) 100 flexible nurses (46%)	√ structure homogeneity	actors, network	-
MacPhee & Scott, 2002[32]	comparative case study ++	√	-	-	-	225 nurses (33%)	√ structure homogeneity	actors, network	T-tests
Mendel et al 2009[33]	comparative case study: T1 and T2 +++	√ (interview)	-	-	-	(2004) 38 organisations (92%), (2006) 59 organisations (93%)	√ connections diffusion stability	network (inter-organisation)	-
Milward & Provan, 1998[52]	multi-case study +++	√ (interview)	-	-	-	32 to 36 agencies for each of 4 service networks, 23 agencies for substance-abuse network (92-100%)	√ connections	network (inter-organisation)	-
Milward & Provan, 2003[38]	multi-case study ++	√ (interview)	-	-	-	40 agencies (100%)	√ connections stability	network (inter-organisation)	-
Mossholder et al., 2005[34]	case study ++	√	-	-	-	374 hospital staff (58%)	√ connections embeddedness	actors, network	survival analysis
Ommen et al. 2009[46]	cross-sectional case study +++	√	-	-	-	454 physicians (61%)	-	actors, organisation	multiple regression

Study	Study Design / Quality	Methodology							
		Survey	Interview	Observation	Document Analysis or Archival Data	Sample Size/ response rate	Social Network Analysis	Level of Social Network Analysis	Other Statistical Analysis
Ormrod et al. 2007[53]	ethnographic study ++	-	√	√	√	3 mental health agencies	-	actors/team	-
Peng et al., 2006[39]	cross-sectional study ++	√	-	-	-	494 hospitals (20%)	-	organisation, network	multiple regression
Rangachari, 2008[40]	multi-case study +++	√	√	-	-	65 staff (100%)	√ brokerage hierarchy density	networks	-
Webster et al., 1999[50]	multi-case study +++	√ (interview)	-	-	-	8 mental health teams: 8-11 in each (100%)	√ connections centrality	actors ,teams	-
West & Barron, 2005:[54] West et al., 1999[55]	cross-sectional study +++	√ (telephone)	-	-	-	50 nursing directors, 50 medical directors (49.5%)	√ connections homogeneity brokerage embeddedness	actors, networks	-
TOTAL	26	23	4	2	6		20		
+++ All of the study quality assessment criteria were fulfilled; ++ Almost all of the criteria were fulfilled; + Some of the criteria were fulfilled; – Few or no criteria were fulfilled.									

Supplementary Material: *Health professional networks as a vector for improving health care quality and safety. A systematic review.*
Cunningham *et al.*

Table S1. Social Network Analysis – Definitions, Theories and Propositions

Item	Researcher	Definition, Theories and Propositions
Actors	Newman, Watts & Strogatz [1] Uzzi [2-3] Burt [4]	People who make up a social network. Actors favour others whom they trust. Actors favour others with whom they exchange information, or upon whom they depend.
Broker relationships	Provan, Fish & Sydow [5] Burt [4]	'To what extent does an organisation span gaps, or structural holes, in a network, and what are the implications of this for the organisation?' 'Organisations that span 'structural holes' are considered to be brokers, often occupying positions of considerable influence.'
Centrality	Bavelas [6] Newman, Watts & Strogatz [1] Webster <i>et al.</i> [7: p. 171]	Within the network, the recognised leader will probably have the position of highest centrality. Based on the study of communication and information flow in a network, Bavelas noted that 'in patterns with a high, localised centrality, organisation evolves more quickly, is more stable, and errors in performance are less. At the same time, however, morale drops. It is inconceivable that morale should not, in the long run, affect stability and accuracy negatively.' The influence of the various 'actors'. 'The most theoretically developed set of network measures for the study of leadership are measures of centrality' (Webster cites: Bavelas [6]; Beauchamp [8]; Bonacich [9]; Freeman [10]; Knoke and Burt [11]; Leavitt [12]; Sabidussi [13]. 'Both individuals and groups can be considered in terms of centrality.'
'Betweenness' centrality	Mendel <i>et al.</i> [14] Hawe, Webster & Shiell [15]	The extent to which an organisation serves as a link or bridge across different parts of the network that would otherwise not be connected. 'The number of times an actor connects pairs of other actors, who otherwise would not be able to reach one another. It is a measure of the potential for control as an actor who is high in 'betweenness' is able to act as a gatekeeper controlling the flow of resources between the alters that he or she connects.'

Table S1: Continued		
Item	Researcher	Definition, Theories and Propositions
Degree centrality	Freeman [10] Mendel et al. [14] Provan, Fish & Sydow [5]	Degree centrality of a point, which is the sum of all other points directly connected to it, signifies activity level. The sheer number of ties that an organisation has with other organisations in the network. "In-degree" and "out-degree" centrality: Calculation of in-degree and out-degree centrality is also possible and is based on the extent to which assets such as resources, information, and clients are coming <i>into</i> an organisation from others in the network versus those being sent <i>out</i> to other organisations.'
Closeness centrality	Hawe, Webster & Shiell [15]	'Based on the notion of distance. If an actor is close to all others in the network, a distance of no more than one, then she or he is not dependent on any other to reach everyone in the network. Closeness measures independence or efficiency. With disconnected networks, closeness centrality must be calculated for each component.'
Cliques	Provan, Fish & Sydow [5]	'Cliques are clusters of three or more organisations connected to one another. At the ego-centric level, the extent of an organisation's connectedness to a clique may affect organisational outcomes in ways that are different than when the organisation is connected only through a dyad.'
Clustering	Newman, Watts & Strogatz [1] Scott [16]	'Occurs when two "actors" have another mutual acquaintance, or several.' 'The intuitive idea of a cluster corresponds to the idea of an area of relatively high density in a graph.'
Cohesion	Hawe, Webster & Shiell [15]	The interconnectedness of actors in a network. Measures of cohesion include: 'Distance': The distance 'between two actors in a network (or nodes in a graph) is calculated by summing the number of distinct ties (lines) that exist along the shortest route between them.' 'Reachability': 'Measures whether actors within a network are related, either directly or indirectly, to all other actors. Actors who are not connected to any other actors are called <i>isolates</i> . 'Density': (see definition below).
Connection diversity	Strogatz [17]	'The links between nodes can have different weights, directions and signs.'

Table S1: Continued		
Item	Researcher	Definition, Theories and Propositions
Datasets (network):		
Attribute datasets	Hawe, Webster & Shiell [15]	Data on the characteristics of the network members.
Relational datasets	Hawe, Webster & Shiell [15]	Social network analysis is the study of structure and involves 'relational' datasets. The structure is derived from the regularities in the patterning of relationships among social entities, which might be people, groups, or organisations.
Degrees	Newman, Watts & Strogatz [1]	The number of 'ties' that 'actors' have to other 'actors'.
Density	Berkman et al. [18] West and Barron [19]	The extent to which the network members are connected to each other (whether a network is dense or loose). 'Where ties are dense, information and influence can spread rapidly among all those who are in frequent contact. Where ties do not exist, on the other hand, dissemination through informal interaction is impossible.'
Duality	Wasserman and Faust [20: p.295]	'The duality in affiliation networks refers specifically to the alternative, and equally important, perspectives by which actors are linked to one another by their affiliation with events, and at the same time events are linked by the actors who are their members.'
Fragmentation	Provan et al. [21]	Are all or most network members connected, either directly or indirectly (that is, through another actor or organisation), or is the network broken up into fragments of unconnected actors or organisations?
Governance	Provan, Fish & Sydow [5]	'What mechanism is used to govern and/or manage the overall network? Even if networks are considered as a distinct form of governance, the mechanism used can considerably vary and range from self-governance, to hub-form or lead-organisation governed, to a network administrative organisation (NAO) model.'
Homophily	McPherson, Smith-Lovin & Cook [22]	This principle - the homophily principle - structures network ties of every type, including marriage, friendship, work, advice, support, information transfer, exchange, co-membership, and other types of relationship. (These authors note that the classic citation in the sociological literature seems to be Lazarsfeld and Merton's [23] study of friendship process in Hilltown and Crafttown.)

Table S1: Continued		
Item	Researcher	Definition, Theories and Propositions
Lines	Hawe, Webster & Shiell [15]	The relational ties connecting actors.
Multiplexity	Hawe, Webster & Shiell [15]	'Actors can have multiple ties with other actors.'
	Provan et al. [21]	'[T]he strength of the relationship between individual network partners, based on the number of types of different links (joint programs, referrals, etc.) they maintain.'
Network centralisation	Mendel et al [14]	A measure of the extent to which a network is dominated by one or a few very central hubs (i.e., nodes with high degree and betweenness centrality)
Network structure	Brass [24]; Hawe, Webster & Shiell [15]	The relationships between network structure and position and access to the resources within those networks.
Network subgroup measures	Hawe, Webster & Shiell [15]	A network can be partitioned, as follows: <i>Component</i> : A portion of the network in which all actors are connected, directly or indirectly, by at least one tie. <i>Clique</i> : A subgroup of actors who are all directly connected to one another and no additional network member exists who is also connected to all members of the subgroup.
Prestige	Wasserman and Faust [20: p.174]	'The prestige of an actor increases as the actor becomes the object of more ties but not necessarily when the actor itself initiates the ties. In other words, one must look at ties directed to an actor to study that actor's prestige.'
Relation	Knoke and Yang [25: p. 7]	'A relation is generally defined as a specific kind of contact, connection, or tie between a pair of actors, or dyad. Relations may be either directed, where one actor initiates and the second actor receives (e.g., advising), or nondirected, where mutuality occurs (e.g., conversing).'
Small-world network	Newman, Watts & Strogatz [1]	A network that exhibits a combination of short paths and social structure, the latter being defined in terms of network clustering.
	Watts and Strogatz [26]	'These systems can be highly clustered, like regular lattices, yet have small characteristic path lengths, like random graphs.'

Table S1: Continued		
Item	Researcher	Definition, Theories and Propositions
Social capital	<p>Coleman [27]</p> <p>Lin [28-29]</p> <p>Brass [24]</p>	<p>Coleman identified three forms of social capital: obligations and expectations, information channels and social norms, and described the social structural conditions under which it arises.</p> <p>'A resource (e.g., access to valuable information, word –of-mouth referrals, and power) available in one's network of relationships.'</p> <p>'Social capital is often operationalised as "network centrality", or the number of connections between an individual and others in a network, which grants the central actor access to those individuals and their resources.'</p>
Social connectivity	Pappas, Flaherty & Wooldridge [30: p. 16]	'Social networks within organisations have been used ... to determine social connectivity based on friendship, trust, communication, and even intergroup conflict.' (See also: Krackhardt and Hanson [31]; LaBianca and Brass [32])
Social influence	Marsden and Friedkin [33]	Social influence 'links the structure of social relations to attitudes and behaviours of the actors who compose a network.' 'The proximity of two actors in a social network is associated with the occurrence of interpersonal influence between the actors.'
Structural complexity	Strogatz [17]	The [network] wiring diagram can be an intricate tangle.
Structural embeddedness	<p>Granovetter [34: p. 35, 35-36]</p> <p>Burt [4]</p> <p>Jones, Hesterly & Borgatti [37]</p> <p>Granovetter [35]</p> <p>Uzzi [3]</p>	<p>The extent to which a 'dyad's mutual contacts are connected to one another'. Structural embeddedness is a function of how many participants interact with one another, how likely future interactions are among participants, and how likely participants are to talk about these interactions.</p> <p>The more structural embeddedness there is in a network, the more information each actor knows about all the other actors and the more constraints there are on each actor's behaviour.</p> <p>'Since structural embeddedness diffuses information throughout a system, it also facilitates the development of macroculture – the common values, norms, and beliefs shared across firms – because parties share perceptions and understandings.'</p> <p>Overreliance on strong ties tends to develop tight, relatively isolated cliques that are not well integrated with the rest of the industry.</p> <p>Over-embeddedness (many strong ties and few weak ties) can lead to feuding, choking off novel information from other parts of the industry, and welfare-like support of weak network members.</p>

Table S1: Continued		
Item	Researcher	Definition, Theories and Propositions
Structural holes	Burt [4]	'Structural holes' are non-redundant relationships where the hole acts as an insulator. It is more beneficial to be the exclusive link between individuals and groups (thus filling a structural hole) who are not themselves tied to each other.
Ties	Wellman[38: p. 86]	The essence of community is its social structure, not its spatial structure. By assessing actual ties between network members, one can empirically test whether community exists and whether that community is defined on the basis of neighbourhood, kinship, friendship, institutional affiliation or other characteristics.
	Newman, Watts & Strogatz [1]	'The pattern of interactions between the actors.' The importance of the number of ties that actors have to other actors, their so-called 'degrees'. For example, in many networks, the distribution of actors' degrees is highly skewed, with a small number having an unusually large number of ties. This skewness could have an impact on the way in which communities operate, including the way information travels through the network and the sustainability of networks.
	Granovetter [35]	Ties connecting actors can be strong or weak.
Transitivity	Mendel et al. [14]	Transitivity measures how well information flows within a network, based on the proportion of times a connection from one node to two others is accompanied (or 'closed') by a connection between the other two nodes (akin to a 'friend of a friend' scenario). It is a measure of the extent to which a network is dominated by one or a few very central hubs.
Trust	Provan et al. [21: p. 605]	Trust refers to 'the quality of the relationship among partners (that is, based solely on formal agreements, rules, and procedures, or on trust and informal norms of reciprocity)'.

References – Table S1

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Table S2: Search terms

SEARCH TERMS FOR SOCIAL NETWORKS (HEALTH PROFESSIONALS)	
1.	'Social network*' AND
2.	'Health care' OR 'Healthcare'
3.	OR 'Healthcare sector' OR 'Health care sector'
4.	OR 'Health personnel'
5.	OR 'Medical staff'
6.	OR 'Workforce'
7.	OR 'Professional practice'
8.	OR 'Delivery of healthcare' OR 'Delivery of health care'
9.	OR 'Interprofessional relations'
10.	OR 'Interpersonal relations'
11.	OR 'Interdisciplinary communication'
12.	OR 'Organi*ational culture'
13.	OR 'Models, organi*ational'

Table S3: Study quality assessment criteria

Study Design	Criteria
All study designs	Presentation of an appropriate research question, clear details of study design and methodology, including dates and sources for data collection, survey techniques, description of analysis, data presentation, discussion of results and study conclusions.
Case studies	Description of case settings and characteristics, adequate sample size and selection, adequate response rates (>60%).
Ethnographic studies	Description of study setting, and methods: observation, interviews, document review. Adequate number of participants observed and adequate observation period.
Cross-sectional study	Description of study setting, and methods used to collect data, adequate size and selection of sample so that participants are likely to be representative of target population, adequate response rates (>60%).
Overall ratings	Criteria
+++	All of the above criteria were fulfilled.
++	Almost all of the above criteria were fulfilled, and those criteria that were not fulfilled were thought unlikely to alter the conclusions of the study.
+	Some of the above criteria were fulfilled, and those criteria that were not fulfilled were thought unlikely to alter the conclusions of the study.
–	Few or no criteria were fulfilled, and it was not clear if the conclusions of the study would alter with their inclusion.

Box S1: Study inclusion criteria

- Publication between 1995 to 2009, inclusive, as most articles using network analysis in the health sector have been published since 1995.
- English
- Empirical research
- Editorials, review articles, and discussion pieces were omitted so that only peer reviewed articles were included. The 'grey literature' was not included as it did not meet criteria of being peer reviewed, and being published in scholarly journals.
- Research had to focus on dealing with some depth on one or more aspects of networks of practicing health professionals, or health service agencies with bearing on health practice, particularly in relation to quality of care and sustainability, i.e., mere mention of the term of 'network' was not sufficient.

Box S2: Review approach

Two reviewers from the team appraised all included reports. By drawing on published checklists;[39-42] quality was assessed according to the following: whether there was a clear and systematic description of the aim of the study; participants; sampling strategy; data collection and analysis methods; results of the study; relationship between the researchers and the participants; context and setting of the study; strengths and weaknesses; and implications of the study. Studies were excluded only after discussion between at least two reviewers.