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Dispersion in Hospital Networks of Shared Patients is Associated with Less Efficient Care

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Abstract

Background: There is growing recognition that healthcare providers are embedded in networks formed by the movement of patients between providers. However, the structure of such networks and its impact on healthcare is poorly understood.

Purpose: We examined the level of dispersion of patient-sharing networks across US hospitals and its association with three measures of care delivered by hospitals that were likely to relate to coordination.

Methodology/Approach: We used data derived from 2016 Medicare Fee-For-Service Claims to measure the volume of patients that hospitals treated in common. We then calculated a measure of dispersion for each hospital based on how those patients were concentrated in outside hospitals. Using this measure, we created multivariate regression models to estimate the relationship between network dispersion, Medicare spending per beneficiary, readmission rates, and emergency department (ED) throughput rates.

Results: In multivariate analysis, we found that hospitals with more dispersed networks (those with many low-volume patient-sharing relationships) had higher spending but not greater readmission rates or slower ED throughput. Among hospitals with fewer resources, greater dispersion related to greater readmission rates and slower ED throughput. Holding an individual hospital's dispersion constant, the level of dispersion of other hospitals in the hospital's network was also related to these outcomes.

Conclusion: Dispersed inter-hospital networks pose a challenge to coordination for patients that are treated at multiple hospitals. These findings indicate that patient-sharing network structure may be an overlooked factor that shapes how healthcare organizations deliver care.

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Practice Implications: Hospital leaders and hospital-based clinicians should consider how the structure of relationships with other hospitals influences the coordination of patient care. Effective management of this broad network may lead to important strategic partnerships.

Keywords

Hospitals; social networks; efficiency; quality; referral patterns

INTRODUCTION

Patients move between multiple providers due to the specialized nature of healthcare, their individual preferences, and chance (Enthoven, 2009; Tinetti, Fried, & Boyd, 2012). Coordinating between providers is a large task: the average physician in the U.S. coordinates with 229 other providers in the delivery of care; 31% of Medicare beneficiaries visit multiple hospitals over a five-year period, accounting for more than half of all hospital visits (Bourgeois, Olson, & Mandl, 2010; Pham, O'Malley, Bach, Saiontz-Martinez, & Schrag, 2009).

Researchers have employed social network analysis to characterize the structure of networks formed by patient movement between physicians and to examine the implication of network structure on patient outcomes (Barnett et al., 2012; Lee et al., 2011). The key insight from this literature is that structures conducive to care coordination — including the concentration of physician relationships, centrality of primary care providers, high levels of informal integration across specialties, and frequent patient sharing among a patient's physicians — are associated with lower costs and, in some cases, higher care quality (Barnett et al., 2012; Funk, Owen-Smith, Kaufman, Nallamothu, & Hollingsworth, 2018; Landon et al., 2018; Pollack, Weissman, Lemke, Hussey, & Weiner, 2013). These findings are specific to networks of individual physicians and it is unclear if similar relationship exist in patient-sharing networks between organizations.

We therefore sought to examine the implications of hospital network structure for health care delivery in the United States. Our study was built on the premise that coordination of patient care between hospitals is challenging and resource-intensive (Tsai, Orav, & Jha, 2015), but essential for efficient and high quality care. One structure that may be particularly relevant to the ability of hospitals to coordinate care is the extent of dispersion in the inter-hospital network of shared patients (Barnett et al., 2012; Landon et al., 2018). Hospitals with dispersed networks have many low-volume patient-sharing relationships and may face greater challenges coordinating with each other hospital. In contrast, hospitals that share many patients with relatively few other hospitals may find it easier, and more compelling, to invest in well-functioning inter-organizational coordination structures and practices with those few hospitals.

We used data derived from Medicare claims to measure hospital network dispersion and examined the extent to which dispersion in hospitals' patient-sharing networks relates to three hospital performance measures: Medicare spending per beneficiary, all-cause readmission rates, and emergency department (ED) arrival to departure time for admitted patients. Our research questions were: First, how dispersed are hospitals' patient-sharing networks? Second, does network dispersion relate to Medicare spending per beneficiary, all-cause readmission rates, and ED arrival to departure time? Third, is the association between network dispersion and hospital performance moderated by a hospital's resources to manage dispersion?

To our knowledge, this is the first study to investigate the relationship between hospitals' patient-sharing networks – specifically, network dispersion – and hospital performance in the U.S. Several initiatives, including accountable care organizations (ACOs), bundled payments, and the regionalization of major surgery, have changed incentives for how to manage patient movement across organizations to ensure more efficient and higher quality care. Evidence on how network dispersion independently relates to hospital performance on can inform strategic insights about how to respond to reform initiatives, dedicate resources to external relationships, manage the external environment, and attract essential resources, such as continued patient referrals (Hillman, Withers, & Collins, 2009; Mascia, Di Vincenzo, & Cicchetti, 2012).

THEORY

Patients movement through readmission, referral, transfer, and patient preference creates complex networks in which hospitals are connected by the patients they share. Hospitals that share patients with many other hospitals, rather than a small set of key partners, have highly dispersed networks. Regardless of the specific reason for patient movement, high levels of dispersion in the hospital network requires investment of formal and informal resources in building inter-hospital relationships and may create challenges to coordinating care.

Several theoretical insights underline why network dispersion may hinder care coordination. The patient sharing network can be thought of as a supply chain aimed at producing health, and research on supply chain management indicates that the intensity of inter-firm relationships and investment in specific communication tools like information technology can influence the quality of collaboration (Prajogo & Olhager, 2012). Similarly, relational coordination highlights the importance of repeated interactions for developing problem solving communication rooted in shared knowledge, familiarity, and respect that improves tacit information exchange (Gittell et al., 2000a; Havens, Vasey, Gittell, & Lin, 2010; Hoffer Gittell, 2002). Evidence on the development of inter-organization routines, pre-specified roles, and codified best practices that facilitate work across organizations similarly highlights the role of repeated interactions and familiarity in the development of well-functioning routines (Coleman, 2003; Holmqvist, 2004). Finally, the development of concrete coordination tools may also depend on dispersion. For instance, the development of interoperable information systems may require hospitals to invest in similar technologies, and it may be difficult to coordinate this investment across many partners (Everson, 2017). Similarly, care pathways that enable coordinated care may be more easily designed and implemented with a smaller number of key partners (Herrigel et al., 2016).

Through these effects, network dispersion may negatively impact patient care: lack of relational coordination and low continuity of care has been found to be associated with increased costs across a range of health settings (Gittell et al., 2000b; Van Walraven, Oake, Jennings, & Forster, 2010), while information exchange has been shown to reduce redundant tests and therapeutic procedures, and lower incidence of medical errors from missing information (Menachemi, Rahurkar, Harle, & Vest, 2018). Heart failure patients provide one salient example of the harm that poor inter-hospital coordination may cause as those patients are frequently misdiagnosed as suffering from pneumonia following readmission, leading to adverse care decisions and exacerbated likelihood of medical errors (Usher et al., 2018). Thus, we hypothesize:

> Hypothesis 1: Hospitals with more dispersed networks display poorer performance in the care they deliver.

Implications of Network Dispersion Environment

Prior literature on inter-organizational networks highlights that the broad environments surrounding individual organizations play a role in shaping organizations' ability to collaborate with their peers (Provan, Fish, & Sydow, 2007). This literature extends the notion of embeddedness by identifying another mechanism through which the environment in which the organization is embedded influences its performance (Mascia, Angeli, & Di Vincenzo, 2015; Uzzi, 1997). It follows that a hospital's ability to develop well-functioning coordination may depend on the network structure of other hospitals with which each hospital shares patients, which we term the *network dispersion environment*. Specifically, hospitals may find it challenging to engage other hospitals in devoting resources to develop coordination and information sharing processes when those hospitals themselves have dispersed networks, which may limit the resources those hospitals have for coordination with any one other hospital. Further, in networks with high dispersion, the potential for network dispersion to negatively impact patient care may increase as patients move between multiple hospitals that have dispersed networks. This would occur if providers practicing at an individual hospital in the network must contact multiple hospitals to identify all relevant patient information. In consequence, hospitals that treat patients that are also treated at other hospitals with high levels of dispersion may experience negative impact on their care.

> Hypothesis 2: Hospitals connected to other hospitals with more dispersed networks display poorer performance in the care they deliver.

Resources to Manage Network Dispersion

Organizational capabilities research highlights that individual organizations vary in their core abilities and that these differences arise from the division of labor between organizations, which then lead to varied experiences, knowledge, and strategies for dealing with their environment (Dosi, Nelson, & Winter, 2001). There are many tools available to coordinate care, including health information exchange, use of care coordinators, and development of clinical networks or care pathways; however, community hospitals may not focus on the development of tools that are outside their core capabilities (Southard, Hedges, Hunter, & Ungerleider, 2005). As such, well-resourced hospitals may have greater capability to coordinate patient care in dispersed networks, much as these organizations have been able to quickly respond to payment reform initiatives that incentivized coordinated care (Dummit et al., 2016). For example, large academic hospitals that routinely serve as referral centers and have access to greater financial resources may be more capable of coordinating with multiple hospitals because such coordination is core to the work of referral centers and tertiary care providers (Coleman, 2003). In contrast, a community hospital operating on slim margins and located in a market with a dispersed network may have limited ability to coordinate with multiple hospitals that also treat their patients. Finally, resources to invest in inter-hospital relationships may be readily available when hospitals belong to the same multihospital system. Formal affiliations are likely to lower barriers to these inter-hospital investments and to motivate clinical integration in order to keep patients within the system. Therefore, even in dispersed networks, hospitals that share many patients within a multihospital system may be able to maintain coordinated care for a large proportion of their patients.

> Hypothesis 3: Greater hospital resources moderate the relationship between dispersion and hospital performance towards zero.

Even if hospitals with greater resources are more capable of managing dispersion in their own network, it is not clear that having more resources will be as useful to manage dispersion in the broader network environment, or if hospitals will feel motivated to do so. Nevertheless, to the extent that resources increase hospitals abilities to manage complex networks, greater access to resources is likely to moderate the relationship between the network environment and hospital efficiency and quality.

> Hypothesis 4: Greater hospital resources moderate the relationship between the network dispersion environment and hospital performance towards zero.

METHODS

Data

We identified all non-federal, short-term hospitals in the 2016 American Hospital Association's (AHA) Annual Survey. We then used the 2016 CareSet Labs HOP Teaming network data file to identify hospital networks (Labs, 2019). The HOP data is an aggregated file derived from Medicare Fee-For-Service claims and contains information on all healthcare providers appearing on Medicare claims, including hospitals and other institutional providers, listed by National Provider Identifiers (NPI). Hospital NPIs were primarily identified using the NPIs listed in the 2016 AHA survey; when NPI was missing the hospital Medicare provider number was identified and mapped to the associated NPI in claims data or the hospital's NPI was found by its address. Each observation in the HOP data consists of three variables: the two providers that share patients, identified by their NPIs, and the number of patients that transitioned from the first provider to the second, aggregated over the course of the year. This approach based on administrative claims captures patients treated at the hospital's inpatient and outpatient settings, including patients seen in the emergency department. We combined this network and hospital data with hospital-level measures derived from Medicare Hospital Compare data for 2016.

Performance Measures—We examined three performance measures as the dependent variables: Medicare spending per beneficiary, 30-day all-cause readmissions, and ED arrival to departure time (i.e., median time from ED arrival to ED departure for admitted ED patients). The Medicare spending per beneficiary (MSPB) measure was adjusted for geographic differences in prices, add-on payments to hospitals, and beneficiary age and severity of illness. This measure is the primary measure used in Medicare's Hospital Value Based Payment initiative to capture hospital efficiency. 30-day all-cause readmissions and ED arrival to departure time are also from Hospital Compare. We selected the readmission measure because readmission rates likely related to the ability of each hospital to provide care for patients prone to multiple healthcare encounters and to coordinate to reduce unnecessary readmissions. The measure was used in a key prior study on hospital networks (Mascia et al., 2015). Like MSPB, the readmission measure was adjusted for patient characteristics. We examined ED arrival to departure time because it was likely related to how quickly ED staff were able to gather information from outside providers to make an informed admission or discharge decision. The MSPB measure was created from hospital data from January 1, 2016 to December 31, 2016, the readmission measure was created from hospital data from July 1, 2015 to June 30, 2016, and the ED measure was created from hospital data from July 1, 2016 to June 30, 2017.

Hospital Network Dispersion—To measure network dispersion, we calculated the number of patients that a hospital shared with each other hospital and divided that value by the total number of patients that the same hospital shared with all other hospitals. We then took the sum of squares of these fractions to generate a measure similar to the Herfindahl-Hirschman Index (HHI), which is commonly used to measure the competition (or concentration) of a market. We subtracted this value from 1, producing a 0 to 1 scale where a hospital that shared all patients with a single other hospital would be a 0 while a hospital with many hospital partners each comprising a very small portion of their total patient population would be close to 1.

Network Dispersion Environment—For each hospital in our data, we generated a measure of the average dispersion of the hospital environment (i.e., all other hospitals with which each hospital shared patients). To do so, we generated a weight by dividing the number of patients the focal hospital shared with each other hospital by the number of patients the focal hospital shared with all other hospitals. We then multiplied the dispersion of each other hospital by this fraction and summed across all other hospitals that the focal hospital shared patients with. Similar to the measure above, this generated a 0 to 1 measure in which a 0 represented very low average dispersion across outside, connected hospitals and a 1 represented very high dispersion.

Network Dispersion Management Resources—We operationalized hospitals' resources for managing dispersion using several variables intended to capture three different types of resources. We first measured the hospital's role as a referral center, which is likely to relate to its ability to manage and gain information about patients treated elsewhere. To do so, we created a scale by combining three levels of hospital size (small [<100 beds], medium [100–399 beds], and large [400+ beds]), teaching status (non-teaching, minor teaching, and major teaching), and five levels of trauma center status (non-trauma, level 4, 3, 2, 1). These three variables were highly correlated (>0.40) and the three-item scale had a Cronbach's alpha of 0.64. This created a single measure ranging from 0–8, which we rescaled to range from 0–8 by dividing by 8. A second important type of hospital resources is financial health, which can be independent of scale. To directly measure financial resources, which could be dedicated to managing complex networks, we used the hospital's total margins (total revenue minus total expenses) from the hospital cost reports from 2016. Finally, a potentially important resource to mitigate dispersed networks is participation in an integrated system. We operationalized system participation for each hospital by calculating the fraction of a hospital's shared patients that were shared within the system.

Control Variables—We controlled for several hospital-related characteristics that might bias the relationship between network dispersion and MSPB, readmissions rate and ED arrival to departure time. General hospital characteristics that may be associated with both dispersion and performance measures included the total number of shared patients with other hospitals, whether the hospital was a general acute care hospital or specialty hospital, hospital case-mix index from the annual Medicare inpatient report, and the referral center status scale. To capture hospital relationships, which may relate closely to network structure and performance, we included variables from the AHA survey measuring the hospital's membership in a multihospital system or network, whether the hospital was part of an accountable care organization (ACO), and whether the hospital participated in a bundled payment program.

We also included several variables to account for market structure, which may be a key factor in creating dispersion and also influence hospital performance. We included an indicator for whether the hospital had an urban or rural location, as well as the number of hospital beds per 1,000 persons and population density from the Area Healthcare Resource File. We also used the Medicare Hospital Service Area file to calculate a hospital-specific Herfindahl-Hirschman Index. To do so, we first calculated the HHI of each ZIP code using the market share of each hospital that treated patients in that ZIP code. We then calculated a hospital-specific HHI by weighting each ZIP code HHI by the proportion of all cases at that hospital that were from that ZIP code and summing across all ZIP codes that the hospital served.

Analytic Plan

Because the data exhibited extreme outliers at low levels of dispersion and margins, we omitted 1% of hospitals with the lowest dispersion and 1% of hospitals with the lowest total margins to avoid biasing our results by these high leverage outliers. After dropping those 30 hospitals with very low levels of dispersion, the final analytic sample included 3,013 non-federal acute care hospitals except in models examining ED wait time, for which the outcome measure was available for 2,881 hospitals.

We validated the measure of hospital network dispersion in three steps. First, we presented visualizations of three hospital networks to three regional experts, identified through the authors' social networks, who confirmed the face validity of the inter-hospital patient sharing data (Appendix Table 1). Next, we graphed networks centered on individual hospitals with varied levels of dispersion and validated that the dispersion measure in fact captured both the number of other hospitals a hospital shared patients with and the concentration of patients across those others. We present this information in Appendix Table

2, which describes each network and the factors driving the measured dispersion. This step indicated that our measure was effectively capturing the structure it was intended to capture. Finally, we regressed the measure of dispersion on several related constructs – including hospital size, teaching status, trauma center status, market concentration, system membership, and number of hospitals within 50 miles – to establish construct validity and found moderate, positive correlations between dispersion and, size, teaching status, and hospitals within 50 miles and negative correlations with system membership and market concentration.

To address our first research question about the overall level of dispersion at hospitals, we plotted a histogram of dispersion. To address our second research question (H1 and H2), we created multivariate regression models predicting MSPB, 30-day all-cause readmission rates, and time in the ED by level of network dispersion. We included control variables that might otherwise bias the estimated relationship between dispersion and performance measures and used heteroskedastic robust standard errors. Several key variables, including MSPB and our measures of dispersion do not have an intuitive scale so it is challenging to infer the size of any observed association in these values. To facilitate interpretation, we standardized these variables such that the coefficients on the variables of interest in all models represented the change in the outcome variable created by a one standard deviation change in the network measure.

Finally, we addressed our third research question (H3 & H4) by examining whether key hospital characteristics associated with greater resources to enable management of a dispersed network moderated the relationship between network dispersion, MSPB, readmissions and time in the ED. In separate regression models, we first interacted each hospital's network dispersion and then network dispersion environment with (1) referral center status, (2) hospital total margins, and (3) proportion of patients shared within a multihospital system. In all models, we included the set of controls described above. For each measure, we would find evidence supporting our hypotheses if we observed a negative sign on the interaction term between greater referral center status and dispersion, total margins and dispersion, and multihospital system volume and dispersion. This study, which uses public and organization-level data, was not considered human subjects research and did not require review by the institutional review board.

RESULTS

Table 1 reports summary statistics for the 3,013 hospitals included in the sample. Before standardization, mean MSPB was 0.99 (SD=0.08); mean ED time to admission was 290 minutes (SD=93); and mean all-cause readmission rate was 15.32 (SD=0.88). The sample included diverse hospitals (e.g., 32% small, 53% medium and 14% large).

The median hospital in the data shared patients with 31 other hospitals but 74% of all patient sharing occurred with the 5 most common hospital partners. Figure 1 displays the overall distribution of dispersion among included U.S. hospitals, which has a long-left tail and is clustered around the median value of 0.84.

In multivariate analysis, we found mixed support for hypothesis 1 (Table 2). In support of the hypothesis, a one standard deviation increase in dispersion was associated with 12.4% of a standard deviation increase in MSPB ($p<0.001$). In contrast, dispersion was not associated with greater readmissions or ED wait times.

We found support for hypothesis 2. Specifically, a one standard deviation increase in dispersion in connected hospital networks was associated with 3.9% of a standard deviation increase in MSPB ($p=0.044$). A one standard deviation increase in network dispersion environment was significantly associated with an increased readmission rate of 0.099 ($p<0.001$), or about 11.3% of a standard deviation in the dependent variable. The network dispersion of connected hospitals was not significantly associated with median time in the ED.

We found support for hypothesis 3 in two of the three tests examining a moderating effect of hospital resources on the relationship between hospital dispersion and MSPB (Table 3). Greater dispersion was associated with greater MSPB ($\beta=0.170$, $p<0.001$) among non-referral center hospitals, but the negative interaction between referral-center status and dispersion ($\beta=-0.025$, $p=0.001$) indicates that this association is reduced among referral center hospitals. We did not observe an interaction between dispersion and total margins in models predicting MSPB. Greater dispersion was also associated with greater MSPB among hospitals that shared the overall average number of patients within a multihospital system ($\beta=0.101$, $p<0.001$), and the interaction between the proportion of patients shared within the system and dispersion was negative such that the association between dispersion and MSPB was less strong in hospitals that shared more patients within the system.

We found mixed support for hypothesis 3 in tests examining a moderating effect of hospital resources on the relationship between hospital dispersion and readmissions (Table 3). The association between dispersion and readmissions among small, non-teaching, non-trauma center hospitals was not significant, but the positive interaction between referral center status and dispersion (interaction $\beta= 0.23$, $p<0.001$) indicates that dispersion was related to higher rates of readmission for larger hospitals. We observed a negative moderating effect of total margins on the relationship between dispersion and readmission ($\beta=-0.053$, $p=0.001$) such that at lower margins greater dispersion was associated with greater readmission rates. We did not observe a moderating effect by intra-system patient sharing.

Similarly, we found mixed support for hypothesis 3 in tests examining whether hospital resources moderated the relationship between hospital dispersion and median time in the ED (Table 3). We did not observe a statistically significant moderating effect by referral center status. However, we did observe a negative moderating effect of total margins on the relationship between dispersion and median time in the ED, ($\beta=-6.68$, $p<0.001$) such that greater dispersion was associated with longer ED wait times in hospitals with lower total margins. For wait times, there was a negative interaction between dispersion and intra-system patient sharing such that dispersion was associated with decreased wait times in hospitals with greater intra-system sharing ($\beta=-2.325$, $p=0.039$).

Finally, we found limited support for hypothesis 4 testing whether hospital resources moderated the relationship between network dispersion environment and performance (Table 4). For non-referral center hospitals, we observed an association between dispersion environment and MSPB (β=0.091, p=0.005); however, the association was attenuated for referral center hospitals (interaction β=−0.151, p<0.011) A more dispersed network environment was associated with greater MSPB among hospitals that shared the average number of patients within a multihospital system (β=0.054, p<0.006), and the interaction between the standardized proportion of patients shared within the system and dispersion was negative (β= −0.090, p<0.001) such that this association did not persist in hospitals that shared a high proportion of patients within the system.

More dispersed network environments were not associated with greater readmission rates for non-referral center hospitals but were associated with greater readmission rates for referral center hospitals (interaction β=0.168, p=0.004). Dispersed network environments were associated with increased readmissions among hospitals sharing the average proportion of patients within the system (β=0.105, p<0.001), and the negative interaction between dispersion environment and same-system patient sharing indicated this relationship was less strong for hospitals that shared more patients within the system (β=−0.37, p=0.019). A more dispersed environment was also associated with shorter ED times in non-referral center hospitals (β=−7.173, p=0.006), but a positive interaction term indicated this relationship was weakened in referral center hospitals (interaction β=13.5, p=0.028). The proportion of patients shared within the system did not influence the association between dispersion environment and ED wait time.

Total margins did not moderate the relationship between dispersed environments and any measured outcome.

DISCUSSION

In this study, we examined the degree of dispersion in hospitals' patient-sharing networks and the influence of dispersion in the patient-sharing network on performance measures of hospital care delivery across the United States. The median hospital shared Medicare patients with more than 30 other hospitals so that, despite sharing many patients with their most common partners, most hospitals had relatively high levels of network dispersion. We found that greater levels of dispersion in a hospital's network of shared patients was associated with higher MSPB, indicating less efficient care. Also, greater dispersion in a hospital's network environment was related to more frequent readmissions. Finally, in moderation analysis, we found some evidence that there was a stronger link between network dispersion of the focal hospital and surrounding environment and MSPB, and ED throughput among hospitals with limited access to resources, though this relationship was reversed for readmissions. Taken together, these findings provide evidence that the inter-hospital network of shared Medicare patients forms a context within which hospitals must work to deliver care, and that dispersion in that network increases the challenge of care delivery.

There is increased interest in inter-provider networks of shared patients (Hollingsworth et al., 2015; Landon et al., 2018). While much of this work has focused on the network of physicians, a stream of research has investigated the structure and implications of the hospital network of shared patients (Brunson & Laubenbacher, 2017). However, there is little previous evidence of the role of hospital patient-sharing networks on the quality and efficiency of care that hospitals offer (Lomi et al., 2014; Mascia et al., 2015; Pallotti & Lomi, 2011). Our study provides evidence from a national hospital sample in the United States that dispersion in the network of shared Medicare patients influences the care offered to those patients by hospitals, holding constant many of the hospital and market characteristics that may contribute to the creation of dispersed networks. Dispersion may effectively capture concerns about care fragmentation and continuity in parallel literatures, and our findings suggest that its impact on care should be further explored. Importantly, the measures we used reflect hospital performance in treating all patients and therefore may reflect both the direct negative impact on patients moving through the network and suggest a spillover effect on other patients that occur because hospitals must dedicate resources to managing the complex network.

Beyond the impact of a hospital's own network, our study finds that dispersion in the networks of *other* hospitals with which the hospital shares patients is related to the performance in care delivery. We therefore provide evidence on the role that the network environment surrounding each organization plays in the organization's performance. Much of the existing literature on physician-level networks takes this phenomenon as implicit by focusing on the aggregate influence of the network structure of a community of providers on patient outcomes, even if that aggregate structure is not relevant to individual physicians or patients (Barnett et al., 2012; Casalino et al., 2015). Our study explicitly shows that the structure of other hospitals' networks is associated with a hospital's performance in delivering care. This idea follows naturally from notions of organizational embeddedness, which has shown how an organization's performance is influenced by the environment surrounding it (Provan, 1984; Uzzi, 1997). In this case, broader dispersion in the surrounding network is likely to create complexity in managing relationships between hospitals and to lead to information fragmentation and care fragmentation.

Finally, in investigating the role of hospital resources on moderating the association between dispersion and hospital performance, we provide some of the first evidence that individual organizations' attributes influence the relationship between patient networks and important outcomes. Our evidence indicates that referral center hospitals are better able to provide efficient care despite dispersed networks, but that dispersion led to greater readmissions at these hospitals. This indicates that these well-resourced hospitals provide more efficient care but may struggle to ensure that needy patients receive appropriate care. One potential reason for this is that the risk-adjustment used in creating measures may not fully account for the complexity of patients moving through the patient sharing network towards referral centers. Similarly, our finding that hospitals that share more patients within multihospital systems are less impacted by dispersed networks indicates that integrated systems can facilitate inter-hospital coordination and that other supra-organizational coordinating entities, like clinical networks and ACOs, may similarly facilitate coordination across patient sharing networks.

Our study is subject to a number of limitations. First, our study did not employ an experimental design and we cannot rule out the potential that omitted variables may confound the relationship between network dispersion and measured outcomes. However, we have adjusted for numerous hospital and market-level covariates to minimize the risk of this source of bias. Second, the publicly available network and outcomes data used in this analysis are at the provide-level and contain little information about the conditions for which patients are treated or the treatment received. In consequence, this study represents a very high-level view of the hospital network and may not capture features of the network important for specific conditions, treatments, or patient populations. Coordination of care may be less important for some patients treated at multiple institutions for unrelated episodes and more important for other patients treated for exacerbations of prior conditions for which detailed histories would be most useful. This limitation may be one reason for the limited effect size observed in our models: the true association between network structure and hospital performance measures may be much stronger for some patients transitioning between organizations than observed here, but in our average estimate in regression models, the effect is ‘washed out’ by patients treated for unrelated episodes and by patients that are not treated elsewhere, which may be less influenced by network structure. Third, in this study we focus on the hospital patient-sharing network. We selected this focus to complement the growing literature on the inter-physician network; however, there are many important patient sharing relationships and this study does not observe the effect of the physician-to-physician, physician-to-hospital network, or the many other pieces of the full healthcare delivery system network. Fourth, the study focuses on Medicare patient networks, which may be more likely than other groups to receive treatment at multiple hospitals because they on average have a greater number of comorbidities. However, because insurance networks do not drive Medicare patients’ choice of provider, they may experience less fragmentation because they can choose the hospital recommended by their providers. Therefore, the generalizability of this data to other populations requires further examination. Fifth, we used total margins as a proxy for hospital’s financial health; however, this measure does not fully capture multidimensional issues related to measuring organizational financial resources. Finally, we theorized that the relationships observed between network dispersion and care are related to communication and coordination practices; however, we are not able to directly examine the relationship between networks and these practices. Further research may empirically investigate the idea that certain network structures correspond to reported improvements in coordination.

PRACTICAL IMPLICATIONS

Our study points towards the potential value to hospital leaders and clinicians considering the wide range of hospitals where their patients receive care and the structure of those relationships, rather than focusing on perceived key competitors or collaborators. Further developing evidence of the impact of the structure of inter-organizational networks on the care patients receive could lead to new insights in how to enact management and policy initiatives that support development of networks that facilitate effective care delivery.

While the field is still growing, evidence on the role of network structures and continued dispersion of networks has the potential to impact public policies and organizational initiatives. For instance, Accountable Care Organizations (ACOs) may encourage hospitals to keep patients within a narrower group of provider partners, as might bundled payment initiatives. Our study also indicates that small hospitals may particularly benefit from developing rich, narrow relationships with few other hospitals. In contrast, it is possible that some hospitals may be able to influence the structure of the overall referral network, for instance by developing specific referral relationships or network affiliations. These initiatives may prove beneficial to the extent that they decrease network dispersion while matching complex patients that have experience fragmented care to hospitals best able to manage their condition and gather information from the broader network.

Outside of some targeted initiatives, hospitals and hospital leadership may have limited control over the other locations where their patients receive care. Instead, our finding points towards the need to consider the structure of the network in which a given hospital is embedded and to develop coordination approaches that 'fit'. In addition to the dispersion structure studied here, patient movement likely varies on related dimensions. For instance, patient movement between hospitals may be view as beneficial and occur within a cooperative relationship between hospitals, as when a patient is referred elsewhere for specialty care. In other cases, transitions may be viewed as the 'loss' of a patient to a competitor, and competitive motives may limit the incentives for hospitals to explicitly coordinate care. Detailed understanding of the structure of the patient sharing network and reasons for patient movement may be crucial to develop coordination strategies. And this may be particularly difficult for smaller and less well-resourced hospitals because network dispersion presents a complex challenge that require a large amount of resources—such that large, high-revenue academic medical centers and multihospital systems are best positioned to manage them.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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REFERENCES

Barnett ML, Christakis NA, O'Malley AJ, Onnela J-P, Keating NL, & Landon BE (2012). Physician patient-sharing networks and the cost and intensity of care in US hospitals. Medical care, 50(2), 152. [PubMed: 22249922]

Bourgeois FC, Olson KL, & Mandl KD (2010). Patients treated at multiple acute health care facilities: quantifying information fragmentation. Archives of internal medicine, 170(22), 1989–1995. [PubMed: 21149756]

Brunson JC, & Laubenbacher RC (2017). Applications of network analysis to routinely collected health care data: a systematic review. Journal of the American Medical Informatics Association, 25(2), 210–221.

Casalino LP, Pesko MF, Ryan AM, Nyweide DJ, Iwashyna TJ, Sun X, … Moody J (2015). Physician Networks and Ambulatory Care-sensitive Admissions. Medical Care, 53(6), 534–541. [PubMed: 25906013]

Coleman EA (2003). Falling through the cracks: challenges and opportunities for improving transitional care for persons with continuous complex care needs. Journal of the American Geriatrics Society, 51(4), 549–555. [PubMed: 12657078]

Dosi G, Nelson R, & Winter S (2001). The nature and dynamics of organizational capabilities: OUP Oxford.

Dummit LA, Kahvecioglu D, Marrufo G, Rajkumar R, Marshall J, Tan E, … Gu Q (2016). Association between hospital participation in a Medicare bundled payment initiative and payments and quality outcomes for lower extremity joint replacement episodes. Jama, 316(12), 1267–1278. [PubMed: 27653006]

Enthoven AC (2009). Integrated delivery systems: the cure for fragmentation. American Journal of Managed Care, 15(12), S284.

Everson J (2017). The implications and impact of 3 approaches to health information exchange: community, enterprise, and vendor-mediated health information exchange. Learning Health Systems, 1(2).

Funk RJ, Owen-Smith J, Kaufman SA, Nallamothu BK, & Hollingsworth JM (2018). Association of Informal Clinical Integration of Physicians With Cardiac Surgery Payments. JAMA surgery, 153(5), 446–453. [PubMed: 29282464]

Gittell JH, Fairfield KM, Bierbaum B, Head W, Jackson R, Kelly M, … Thornhill T (2000a). Impact of relational coordination on quality of care, postoperative pain and functioning, and length of stay: a nine-hospital study of surgical patients. Medical Care, 38(8), 807–819. [PubMed: 10929993]

Gittell JH, Fairfield KM, Bierbaum B, Head W, Jackson R, Kelly M, … Thornhill T (2000b). Impact of relational coordination on quality of care, postoperative pain and functioning, and length of stay: a nine-hospital study of surgical patients. Medical care, 807–819. [PubMed: 10929993]

Havens DS, Vasey J, Gittell JH, & Lin WT (2010). Relational coordination among nurses and other providers: impact on the quality of patient care. Journal of Nursing Management, 18(8), 926–937. [PubMed: 21073566]

Herrigel DJ, Carroll M, Fanning C, Steinberg MB, Parikh A, & Usher M (2016). Interhospital transfer handoff practices among US tertiary care centers: A descriptive survey. Journal of hospital medicine, 11(6), 413–417. [PubMed: 27042950]

Hoffer Gittell J (2002). Coordinating mechanisms in care provider groups: Relational coordination as a mediator and input uncertainty as a moderator of performance effects. Management science, 48(11), 1408–1426.

Hollingsworth JM, Funk RJ, Garrison SA, Owen-Smith J, Kaufman SR, Landon BE, & Birkmeyer JD (2015). Differences between physician social networks for cardiac surgery serving communities with high versus low proportions of black residents. Medical Care, 53(2), 160–167. [PubMed: 25517071]

Holmqvist M (2004). Experiential learning processes of exploitation and exploration within and between organizations: An empirical study of product development. Organization science, 15(1), 70–81.

Iwashyna TJ (2012). The incomplete infrastructure for interhospital patient transfer. Critical care medicine, 40(8), 2470–2478. [PubMed: 22809914]

Labs C (2019). DocGraph Hop Teaming Retrieved from https://careset.com/docgraph-hop-teaming/

Landon BE, Keating NL, Onnela J-P, Zaslavsky AM, Christakis NA, & O'Malley AJ (2018). Patient-sharing networks of physicians and health care utilization and spending among Medicare beneficiaries. JAMA internal medicine, 178(1), 66–73. [PubMed: 29181504]

Lee BY, McGlone SM, Song Y, Avery TR, Eubank S, Chang C-C, … Platt R (2011). Social network analysis of patient sharing among hospitals in Orange County, California. American journal of public health, 101(4), 707–713. [PubMed: 21330578]

Lomi A, Mascia D, Vu DQ, Pallotti F, Conaldi G, & Iwashyna TJ (2014). Quality of care and interhospital collaboration: a study of patient transfers in Italy. Medical Care, 52(5), 407. [PubMed: 24714579]

Mascia D, Angeli F, & Di Vincenzo F (2015). Effect of hospital referral networks on patient readmissions. Social Science & Medicine, 132, 113–121. [PubMed: 25795994]

Menachemi N, Rahurkar S, Harle CA, & Vest JR (2018). The benefits of health information exchange: an updated systematic review. Journal of the American Medical Informatics Association

Pallotti F, & Lomi A (2011). Network influence and organizational performance: The effects of tie strength and structural equivalence. European Management Journal, 29(5), 389–403.

Pham HH, O'Malley AS, Bach PB, Saiontz-Martinez C, & Schrag D (2009). Primary care physicians' links to other physicians through Medicare patients: the scope of care coordination. Annals of Internal Medicine, 150(4), 236–242. [PubMed: 19221375]

Pollack CE, Weissman GE, Lemke KW, Hussey PS, & Weiner JP (2013). Patient sharing among physicians and costs of care: a network analytic approach to care coordination using claims data. Journal of general internal medicine, 28(3), 459–465. [PubMed: 22696255]

Prajogo D, & Olhager J (2012). Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration. International Journal of Production Economics, 135(1), 514–522.

Provan KG (1984). Interorganizational cooperation and decision making autonomy in a consortium multihospital system. Academy of management review, 9(3), 494–504. [PubMed: 10267617]

Provan KG, Fish A, & Sydow J (2007). Interorganizational networks at the network level: A review of the empirical literature on whole networks. Journal of management, 33(3), 479–516.

Southard PA, Hedges JR, Hunter JG, & Ungerleider RM (2005). Impact of a transfer center on interhospital referrals and transfers to a tertiary care center. Academic emergency medicine, 12(7), 653–657. [PubMed: 15995099]

Sun BC, Burstin HR, & Brennan TA (2003). Predictors and outcomes of frequent emergency department users. Academic emergency medicine, 10(4), 320–328. [PubMed: 12670845]

Tinetti ME, Fried TR, & Boyd CM (2012). Designing health care for the most common chronic condition—multimorbidity. Jama, 307(23), 2493–2494. [PubMed: 22797447]

Tsai TC, Orav EJ, & Jha AK (2015). Care fragmentation in the postdischarge period: surgical readmissions, distance of travel, and postoperative mortality. JAMA surgery, 150(1), 59–64. [PubMed: 25472595]

Usher M, Sahni N, Herrigel D, Simon G, Melton GB, Joseph A, & Olson A (2018). Diagnostic Discordance, Health Information Exchange, and Inter-Hospital Transfer Outcomes: a Population Study. Journal of general internal medicine, 1–7.

Uzzi B (1997). Social structure and competition in interfirm networks: The paradox of embeddedness. Administrative science quarterly, 35–67.

Van Walraven C, Oake N, Jennings A, & Forster AJ (2010). The association between continuity of care and outcomes: a systematic and critical review. Journal of evaluation in clinical practice, 16(5), 947–956. [PubMed: 20553366]

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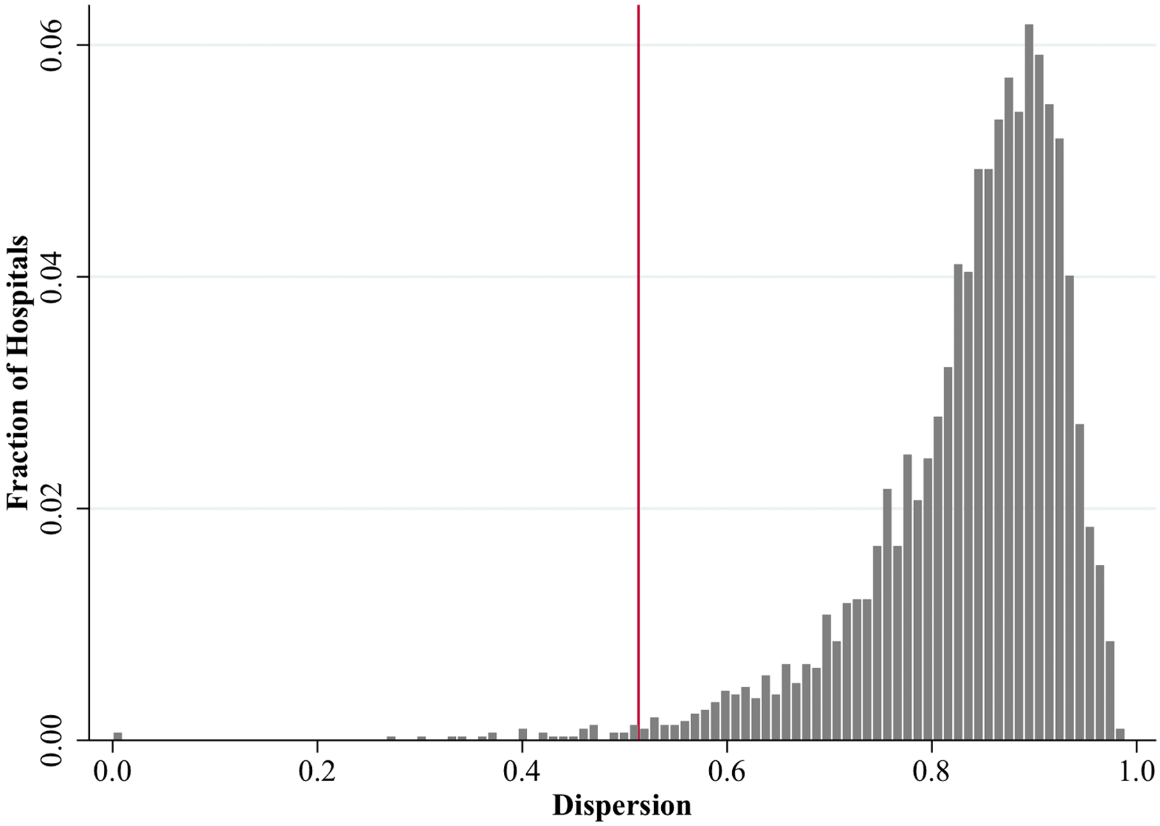

Figure 1.
Distribution of hospital network dispersion

Table 1.

Mean and Standard Deviation of Study Variables.

	Mean or Percent (N=3,013)	Standard Deviation
Medicare Spending Per Beneficiary	0.99	0.08
All-Cause Readmission Rate	15.32	0.88
Median Time from ED Arrival to Departure for Admitted ED Patients *	290	93
Hospital Dispersion	0.84	0.09
Dispersion Environment	0.87	0.05
Total Shared Patients (in thousands)	7.16	8.45
Total Margins	0.00	0.23
System Member	72%	45%
Network Member	38%	49%
Small	32%	47%
Medium	53%	50%
Large	14%	35%
Not Trauma Center	30%	46%
Level 1. Regional Resource Center	4%	18%
Level 2. Community Trauma Center	6%	23%
Level 3. Rural Trauma Center	7%	26%
Level 4. Other	2%	15%
Non-teaching	29%	45%
Major Teaching	7%	26%
Minor Teaching	16%	37%
Rural Referral Center	6%	24%
Population Density (Thousands per Square Mile)	0.01	0.04
Hospital Market Concentration	0.28	0.09
Urban (Omitted: Rural)	75%	43%
Beds per 1,000 persons	3.38	3.29
General Acute Care (Ref: Other)	96%	19%
ACO Participation	16%	36%
Bundled Payment Participation	20%	40%
CMI	1.62	0.35

* n=2,881 due to limited availability of this quality measure

Table 2.

Multivariate Analysis of Associations between Network Dispersion and Efficiency, Readmissions and ED Throughput.

	Standardized MSPB	All Cause-Readmission Rate	Median Time from ED Arrival to Departure for Admitted ED Patients
Standardized Dispersion	0.124 **	0.030 †	0.617
	(0.021)	(0.018)	(1.544)
Standardized Connected Hospital Dispersion	0.039 *	0.099 **	−2.363
	(0.019)	(0.019)	(1.733)
Total Shared Patients (in thousands)	−0.001	0.009 **	0.330
	(0.002)	(0.002)	(0.233)
System Member	0.056	0.030	−5.164
	(0.045)	(0.036)	(3.731)
Network Member	−0.001	−0.097 **	−2.609
	(0.036)	(0.035)	(3.212)
Total Margins	−0.197 *	−0.114 *	−17.912 *
	(0.081)	(0.057)	(7.151)
Referral Center Scale	0.076	0.410 **	56.644 **
	(0.076)	(0.083)	(9.215)
Rural Referral Center	0.178 **	0.175 *	1.411
	(0.058)	(0.073)	(5.349)
Population Density (Thousands per Square Mile)	0.031	2.827 **	584.270 **
	(0.347)	(0.838)	(78.694)
Hospital Market Concentration	−1.545 **	−0.231	−72.560 **
	(0.226)	(0.241)	(22.247)
Urban (Omitted: Rural)	0.541 **	0.222 **	38.730 **
	(0.049)	(0.038)	(3.588)
Beds per 1,000 persons	0.010 **	0.019 **	−1.490+
	(0.004)	(0.006)	(0.783)
General Acute Care (Ref: Other)	0.243 †	0.081	136.635 **
	(0.130)	(0.113)	(12.778)
ACO Participation	−0.066 †	−0.222 **	−5.050
	(0.035)	(0.037)	(3.277)
Bundled Payment Participation	−0.069 †	−0.004	1.366
	(0.039)	(0.047)	(4.211)
CMI	0.084	−0.704 **	41.420 **
	(0.091)	(0.062)	(7.360)
Constant	−0.419 †	16.078 **	65.125 **
	(0.221)	(0.169)	(19.180)

	Standardized MSPB	All Cause-Readmission Rate	Median Time from ED Arrival to Departure for Admitted ED Patients
Observations	3,013	3,013	2,881 ††
R-squared	0.118	0.125	0.261

** p<0.01

* p<0.05

† p<0.10

standard errors calculated using heteroskedastic robust standard errors

†† reduced sample size due to limited availability of this quality measure in Hospital Compare data.

Table 3.

Moderation of Associations between Dispersion and Three Performance Measures

VARIABLES	Standardized MSPB	All Cause-Readmission Rate	Median Time from ED Arrival to Departure for Admitted ED Patients
1. Hospital Referral Scale			
Standardized Dispersion Environment	0.170**	−0.020	−1.033
	(0.028)	(0.023)	(2.042)
Referral Center Scale	0.136+	0.343**	54.700**
	(0.079)	(0.085)	(9.192)
Dispersion Environment * Referral Center Scale	−0.203**	0.225**	6.948
	(0.062)	(0.066)	(6.150)
2. Total Margins			
Standardized Dispersion	0.118**	0.031+	0.506
	(0.020)	(0.019)	(1.574)
Total Margins	−0.046*	−0.027*	−4.140*
	(0.018)	(0.013)	(1.660)
Standardized Dispersion *Total Margins	−0.019	−0.053**	−6.678**
	(0.018)	(0.016)	(1.451)
3. Intra−System Patient Sharing			
Standardized Dispersion	0.101**	0.020	0.129
	(0.021)	(0.019)	(1.560)
System Patient Sharing	−0.152**	−0.074**	−4.710**
	(0.019)	(0.017)	(1.655)
Standardized Dispersion * System Patient Sharing	−0.039**	−0.026*	−2.325*
	(0.015)	(0.013)	(1.127)

** p<0.01

* p<0.05

† p<0.10

Robust standard errors in parentheses; Observations = 3,013 in MSPB and Readmission models, and 2,881 in ED Time Models due to limited availability of the ED measure in Hospital Compare.

All moderation analyses include the covariates from the initial analysis.

Table 4.

Moderation of Associations between Dispersion Environment and Three Performance Measures

VARIABLES	Standardized MSPB	All Cause-Readmission Rate	Median Time from ED Arrival to Departure for Admitted ED Patients
1. Hospital Referral Scale			
Standardized Dispersion Environment	0.091**	0.041	−7.173**
	(0.032)	(0.026)	(2.596)
Referral Center Scale	0.076	0.410**	56.784**
	(0.076)	(0.083)	(9.211)
Dispersion Environment * Referral Center Scale	−0.151*	0.168**	13.571*
	(0.059)	(0.059)	(6.160)
2. Total Margins			
Standardized Dispersion Environment	0.032+	0.097**	−2.441
	(0.019)	(0.019)	(1.745)
Total Margins	−0.043*	−0.021	−4.027*
	(0.018)	(0.016)	(1.582)
Total Margins * Standardized Dispersion Env.	−0.011	−0.014	−0.576
	(0.017)	(0.024)	(1.393)
3. Intra−System Patient Sharing			
Standardized Dispersion Environment	0.054**	0.105**	−2.414
	(0.020)	(0.020)	(1.748)
System Patient Sharing	−0.152**	−0.070**	−3.564*
	(0.019)	(0.016)	(1.539)
Standardized Dispersion *System Patient Sharing	−0.090**	−0.037*	0.281
	(0.014)	(0.016)	(1.198)

** $p<0.01$

* $p<0.05$

† $p<0.10$

Robust standard errors in parentheses; Observations = 3,013 in MSPB and Readmission models, and 2,881 in ED Time Models due to limited availability of the ED measure in Hospital Compare.

All moderation analyses include the covariates from the initial analysis.