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Patient-Sharing Networks of Physicians and Health Care Utilization and Spending Among Medicare Beneficiaries

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IMPORTANCE Physicians are embedded in informal networks in which they share patients, information, and behaviors.

OBJECTIVE We examined the association between physician network properties and health care spending, utilization, and quality of care among Medicare beneficiaries.

DESIGN, SETTING, AND PARTICIPANTS In this cross-sectional study, we applied methods from social network analysis to Medicare administrative data from 2006 to 2010 for an average of 3 761 223 Medicare beneficiaries per year seen by 40 241 physicians practicing in 51 hospital referral regions (HRRs) to identify networks of physicians linked by shared patients. We improved on prior methods by restricting links to physicians who shared patients for distinct episodes of care, thereby excluding potentially spurious linkages between physicians treating common patients but for unrelated reasons. We also identified naturally occurring communities of more tightly linked physicians in each region. We examined the relationship between network properties measured in the prior year and outcomes in the subsequent year using regression models.

MAIN OUTCOMES AND MEASURES Spending on total medical services, hospital, physician, and other services, use of services, and quality of care.

RESULTS The mean patient age across the 5 years of study was 72.3 years and 58.5% of the participants were women. The mean age across communities of included physicians was 49 years and approximately 78% were men. Mean total annual spending per patient was $10 051. Total spending was higher for patients of physicians with more connections to other physicians ($1009 for a 1-standard deviation increase, $P < .001$) and more shared care outside of their community ($172, $P < .001$). Spending on inpatient care was slightly lower for patients of physicians whose communities had higher proportions of primary care physicians (−$38, $P < .001$). Patients cared for by physicians linked to more physicians also had more hospital admissions and days (0.02 and 0.18, respectively; both $P < .001$ for a 1-standard deviation increase in the number of connected physicians), more emergency visits (0.02, $P < .001$), more visits to specialists (0.37, $P < .001$), and more primary care visits (0.11, $P < .001$). Patients whose physicians' networks had more primary care physicians had more primary care visits (0.44, $P < .001$) and fewer specialist and emergency visits (−0.33 [$P < .001$] and −0.008 [$P = .008$], respectively). The various measures of quality were inconsistently related to the network measures.

CONCLUSIONS AND RELEVANCE Characteristics of physicians' networks and the position of physicians in the network were associated with overall spending and utilization of services for Medicare beneficiaries.

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Variation in the quantity, types of services, and quality of care received by patients in different areas of the country have been well documented.[1-3] These variations exist both across large regions of the country and within regions, suggesting that the local milieu influences care. In part, these practice patterns might arise from physicians actively sharing clinical information among themselves through formal and informal discussions and observations (eg, of patient medical records) that occur in the process of providing care to shared patients.[4]

The influence of social networks of physicians on physician decision-making and practice patterns has been neglected despite its potential importance. Previously, we used validated methods based on patient sharing to define professional networks among physicians, and showed how these networks varied across geographic regions.[5,6] Herein, we examine the association between characteristics of local physician networks and selected outcomes of care including spending and measures of the quantity and quality of care.

Key Points

Question Are physician networks associated with health care spending, utilization, and quality of care for Medicare beneficiaries?

Findings In this social network analysis of Medicare data, total spending was higher for patients of physicians with more connections to other physicians and more shared care outside of their network. Patients whose physicians' networks had more primary care physicians had more primary care visits and fewer specialist and emergency visits.

Meaning Characteristics of physicians' networks and the position of physicians and hence their patients within the network are associated with overall spending and utilization of services for Medicare beneficiaries.

Methods

Overview

We used physician encounter data from the Medicare program to define networks of physicians based on shared patients.[7] A social network is defined by a set of actors and the relationships or connections that link these actors together. Social network analysis characterizes the structure of a social system and can be used to understand how this structure is associated with the behavior of constituent actors. In the present application, nodes represent physicians and ties (or edges) arise from patients shared between physicians. We use the presence of shared patients to infer information-sharing relationships between 2 or more physicians. Ties vary in their "strength" according to the number of shared patients, with more shared patients implying stronger connections between physicians, an approach we have previously validated.[8] This study was approved by the institutional review board of Harvard Medical School with a waiver of consent for participants in the study.

Identifying the Sharing of Patients

Shared patients were identified using Medicare claims from 2005 to 2010 for 100% of Medicare beneficiaries (including those under age 65 years) living in 50 market areas (defined as hospital referral regions [HRRs]) randomly sampled with probability proportional to their size (number of Medicare beneficiaries) and distributed throughout the United States.[9] In addition, the Boston HRR was included to aid in the development and testing of our methods since it is familiar to us. Our analyses included patients enrolled in Parts A and B of fee-for-service Medicare, excluding patients enrolled in Medicare Advantage plans for whom encounter data are not available.

We defined encounters with physicians based on paid claims in the carrier file. We excluded claims for nondirect patient care specialties or specialties where individual physicians were not selected (eg, anesthesia, radiology). We identified all evaluation and management services for inpatient and outpatient care, and also included procedures with a relative value unit (RVU) value of at least 2.0 to capture surgical procedures that often are reimbursed via bundled fees that include preprocedure and postprocedure assessments. We excluded claims for laboratory and other services not requiring a physician visit. We also excluded physicians who saw fewer than 30 Medicare patients during a year or who practice outside of the included HRRs.

Constructing Physician Networks

We identified physician networks by connecting pairs of physicians who share patients with one another durring an episode of care, which we measured using Optum's Episode Treatment Group (ETG) software (version 8.3, Optum).[10-13] This method allowed us to eliminate ties between physicians that were unlikely to be true information-sharing relationships, such as between an ophthalmologist and an orthopedic surgeon for a patient who happened to be treated over the course of a year for both cataracts and knee pain. The structural backbone from which we discerned physician networks was a patient-physician "bipartite" or 2-mode network, which means that nodes in the network can be partitioned into 2 sets, physicians and patients, and that all relationships link nodes from 1 set to the other.[14] We formed a unipartitite (physician-physician) network[15,16] by connecting each pair of physicians who shared patients with one another. Our approach to constructing such networks is described in a previous publication.[6] Importantly, although ownership, network affiliations, and, to a lesser extent, managed care "network" inclusion could influence the existence of these types of relationships, our hypotheses were conditional on the relationships we observed, and not what might have motivated them.

Within each HRR, we further partitioned the network into distinct network communities (communities), defined as groups of physicians who were more interconnected than would be expected by chance.[17] We identified communities in each HRR network using the method of modularity maximization introduced by Newman[18] and refined by Newman and Girvan[19] to assign each physician to a single community, and hence to one of several distinct, nonoverlapping groups of physicians.[20] We previously showed that this approach identifies groups of physicians with close working relationships who keep most patient care within the community.[5] We applied this approach annually.

Assigning Patients to Primary Care Physicians (PCPs)

We assigned each beneficiary to the single PCP (defined as internal medicine, family practice, or general practice) who had the most contact with the patient, reflected in providing the plurality of his/her outpatient evaluation and management visits. We used the same algorithm to assign patients with no PCP visits to a specialist physician.

Network Measures of Interest

We defined the following network measures at the level of individual physicians in each network and community.

Degree is defined as the number of doctors connected to a given physician through patient sharing in the entire HRR. To adjust for the effect of patient volume on degree, we further calculated adjusted degree by dividing the observed degree by predicted degree from a regression of degree on the physician's number of patients and its square. We also present descriptive data on the number of connected physicians per 100 Medicare beneficiaries cared for. We hypothesized that patients of physicians who were connected to larger numbers of other physicians would have higher utilization of services and spending as their burden of coordinating care is increased.

Physician dispersion quantifies the extent to which a physician's patients are treated by other physicians outside their community. This measure ranges from 0, indicating that all of the physician's patients' visits are to physicians assigned to the same community, to 1, indicating that none of the visits are to physicians in the same community. Similarly, we hypothesized that patients of physicians whose care was dispersed over different communities of physicians would have higher utilization and spending.

Percent PCPs is a community-level measure of the percent of physicians included in the community who are PCPs. We hypothesized that patients cared for in PCP-centric communities would have lower spending and lower use of specialty services.

Medical Spending and Utilization Outcomes

For each beneficiary, we calculated total standardized annual spending for each year from 2006 to 2010 for all services covered by parts A and B by summing Medicare reimbursements, patient cost sharing (coinsurance), and payments from supplemental insurance and other primary payers. Standardized cost differs from actual Medicare payment in 2 important ways. First, standardized cost incorporates the full allowed reimbursement from all payment sources. Second, standardized cost eliminates the effects of various adjustments Medicare makes in setting local payment rates, such as geographic payment differences for local input price variations and differential payments across classes of providers (eg, disporportionate share and graduate medical expenditure payments; cost-based reimbursement of critical access hospitals vs diagnosis related group-based prospective payment for most other short-term hospitals). We examined total spending and spending on inpatient services, physician services, outpatient services, skilled nursing facilities, and hospice use. We also analyzed annual counts of hospital admissions (excluding transfers), hospital days, emergency department visits, PCP visits, and specialist visits.

Quality of Care

For beneficiaries hospitalized during each calendar year, we identified readmissions within 30 days of discharge to estimate the fraction of hospitalized beneficiaries readmitted at least once. We also constructed from claims data several process measures of quality of care, adapted from the Healthcare Effectiveness Data and Information Set (HEDIS): screening mammography for women ages 52 to 69 years; 3 services for beneficiaries with diabetes, including hemoglobin A1c and low-density lipoprotein (LDL) cholesterol testing, and diabetic retinal examination within the year, as well as a measure of receipt of all 3 services; and LDL testing for those with cardiovascular disease. We also analyzed the Prevention Quality Indicators (PQIs) developed with the support of the Agency for Healthcare Research and Quality (AHRQ).[21] Prevention quality indicators can be used to assess the quality of care for ambulatory care-sensitive conditions for which good outpatient care can potentially prevent the need for hospitalization, or for which early intervention can prevent complications or more severe disease. Because these types of admissions are relatively infrequent, we stratified PQIs into acute and chronic categories and created composite measures in both of these domains consisting of any acute or any chronic PQI.

Physician Characteristics

We used billing zip code and specialty designation from the Medicare claims (defined based on the plurality of submitted claims) to assign a principal specialty and practice location. We excluded physicians (<1%) for whom we could not identify a dominant specialty or practice location. We classified physicians as PCPs or specialist physicians.

Statistical Analyses

Bivariate differences were evaluated using 2-sided *t* tests or χ^2 tests at the 5% level. We estimated several versions of multivariable linear regression models to examine the relationship between selected network measures and outcomes of interest noted above, entered first individually and then all together into a single model. The β coefficients for each of the variables can be interpreted as a change in the outcome of interest for each standard deviation change in the independent variable of interest (standardized effect size). All models included patient age (in 5-year categories), hierarchical condition categories score calculated based on diagnosis from the prior calendar year, race/ethnicity (white, black, hispanic, other), an indicator of whether the patient was on Medicaid, urban/rural location (rural, large rural, urban), number of physicians in the community (categorized by quartile of size as well as continuously), and a fixed effect for hospital referral region to adjust for regional practice factors.[22,23] We explored 2

Table 1. Patient Characteristics

Characteristic	All, Mean (IQR)
No.	3 760 623
Age, y	72.3 (67.0-80.0)
Female, %	58.5
Race, %	
White	85.3
Black	8.8
Other	3.2
Medicaid, %	21.0
HCC score	1.4 (0.6-1.7)
Included patients per hospital referral region, No.	73 737.7 (29 205.0-96 136.0)
Assigned patients per community, No.	10 039.0 (3 992.2-13 459.0)

Abbreviations: HCC, hierarchical condition categories; IQR, interquartile range.

Table 2. Physician and Community Network Characteristics

Characteristic	Mean (SD) Across Communities	Range Across Communities[a]
Physician characteristics		
Age, y	49.1 (2.2)	47.6-50.5
Male sex, %	78.3 (7.2)	73.6-83.6
Primary care, %	39.7 (1.2)	33.8-46.5
Medical specialties, %	34.7 (10.8)	28.3-40.0
Surgical specialties, %	25.6 (9.8)	20.4-29.3
Physician dispersion measure	0.63 (0.18)	0.54-0.77
Degree per 100 patients	49.4 (33.7)	28.1-61.7
Adjusted degree[b]	0.95 (0.45)	0.64-1.17
Network characteristics		
Physicians per community	216.6 (229.1)	72-264
Communities per HRR, mean	7.3	5.0-9.0
No. of ties, mean	7654 (11 025)	1010-8759
Primary care, %	39.7 (11.9)	33.8-46.5

[a] Interquartile range.

[b] Adjusted degree is calculated by dividing the observed degree by predicted degree from a regression of degree on the physician's number of patients and its square.

specifications for accounting for the clustering of observations in communities: designating community as a random effect in a hierarchical generalized linear model and fitting marginal regression models with variances adjusted for clustering using generalized estimating equations (GEE). Mixed-effect models typically assume that the random effects are normally distributed and are independent of every predictor in the model. In contrast, GEE models avoid these distributional and structural assumptions but do make a slightly stronger assumption about the missing data mechanism than mixed-effect models. Because there are almost no missing data and the conclusions were the same under both, we present the marginal regression (GEE-based) findings because this approach avoids the parametric assumptions of the hierarchical model, resulting in more robust results.

The generalized linear model used for the analysis of each outcome depends on the form of the outcome. Cost was analyzed by regressing its log on the predictors using a linear regression model specification and an independent working correlation model so that the point estimates corresponded to those obtained by the ordinary least squares estimator. Community totals for hospital admissions and days in hospital were analyzed as Poisson counts with a log link and an offset equal to the log of the patient population attributed to the community, effectively modeling per-patient rates for each measure. Finally, the quality measures were binary (eg, readmitted or not) and so were analyzed using a logistic regression model.

For the process quality models, we also adjusted for the number of visits because increased contact with the health care system is associated with greater receipt of screening and preventive services.[24] All analyses presented were performed with the Genmod procedure in SAS statistical software (version 9.2, SAS Inc).[25]

Results

We studied an average of 3 761 223 Medicare beneficiaries per year from 51 HRRs who were seen by 40 241 physicians practicing in those HRRs. The mean patient age across the 5 years of study was 72.3 years and 58.5% of the participants were women (**Table 1**).

The mean age across communities of included physicians (**Table 2**) was 49 years and 78.3% were men. Almost 40% of the physicians were classified as PCPs. The mean adjusted degree across communities (the ratio of the observed number of physicians with whom the physician shared care to expected number based on their Medicare patient caseload) was 0.95 and the mean of the physician dispersion measure was 0.61, indicating that on average approximately 60% of the visits by a physician's patients were to physicians outside of their network community (interquartile range across communities, 0.50-0.73). The network measures we examined were reasonably stable year over year.

Differences in Spending and Utilization According to Network Characteristics or Position

Spending and Utilization of Services

Mean total standardized spending (in 2010 dollars) was $10 051, including inpatient ($3533), physician ($2874), and hospital outpatient ($3526) spending and other categories. A 1-standard deviation increase in the adjusted degree of the assigned PCP was associated with an increase in total spending of $1009 ($P < .001$) (**Table 3**). The largest increases in spending were for inpatient services ($390, $P < .001$) and hospital outpatient services ($149, $P < .001$).

The extent to which the care provided to a physician's assigned patients was dispersed outside of the physician's network was also associated with higher spending, but to a lesser extent than for adjusted degree discussed above. A 1-standard deviation increase in physician dispersion was associated with a $172 ($P < .001$) increase in spending.

A 1-standard deviation increase in the percent PCPs in the community, a community-level measure, was associated with

Table 3. Adjusted Relationship Between Network Characteristics and Medicare Spending, Utilization, and Quality (Each Measure Analyzed in a Separate Model)

Characteristic	Mean	Difference for a 1-Standard Deviation Increase in: Adjusted Degree	*P* Value	Physician Dispersion	*P* Value	PCP, %	*P* Value
Total spending, $	10 051	1009	<.001	172	<.001	−94	.22
Spending by category, $							
Hospital inpatient	3533	73	<.001	13.64	.002	−38	<.001
Physician	2874	191	<.001	46.24	<.001	−11	.45
Hospital outpatient department	3526	388	<.001	58.23	.004	−49	.42
Hospice	118	0	.66	−2.0	.15	0	.64
Utilization of services							
Admissions[a]	0.38	0.02	<.001	0.01	<.001	−0.0008	.69
Hospital days	2.48	0.18	<.001	0.09	<.001	−0.02	.29
Primary care physician office visits	5.53	0.11	.004	0.01	.70	0.44	<.001
Specialty office visits	6.50	0.37	<.001	0.09	<.001	−0.33	<.001
Emergency department visits	0.64	0.02	<.001	−0.005	.02	−0.008	.008
Quality of care							
Any 30-day readmission, %	18.3	0.5	<.001	0.2	.02	−0.2	.03
Acute PQI (per 100)	2.4	0.1	<.001	0.1	<.001	0.01	.40
Chronic PQI (per 100)	2.9	0.2	<.001	0.1	<.001	0.08	.006
Mammography, %	47.3	−1.4	<.001	−2.4	<.001	−1.9	<.001
Diabetes							
LDL cholesterol testing, %	83.1	−2.2	.03	−0.9	.22	0.2	.85
Hemoglobin A_{1c} testing, %	88	−1.9	.07	−1.1	.17	−4.6	<.001
Retinal examination, %	60.3	0.7	.11	−2.3	<.001	−2.2	<.001
All 3 services, %	49.4	0.3	.54	−1.8	<.001	−1.4	<.001
Cardiovascular disease							
LDL testing, %	79.4	−4.3[a]	<.001	−3.0	<.001	2.1	.006

Abbreviations: LDL, low-density lipoprotein; PCP, primary care physician; PQI, Prevention Quality Indicators.

[a] Hospitalization counts exclude transfers.

a $94 decrease in total spending, but this difference was not statistically significant. There was a small statistically significant decrease on spending for hospitalizations (−$38, *P* < .001).

Consistent with the spending findings, a 1-standard deviation increase in adjusted degree was associated with more hospital admissions and days (0.02 and 0.18 respectively, both *P* < .001), more emergency visits (0.02, *P* < .001), more visits to specialists (0.37, *P* < .001), and more primary care visits (0.11, *P* < .001). Patients whose physicians' networks had more PCPs had more primary care visits (0.44, *P* < .001), and fewer specialist and emergency visits (−0.33 [*P* < .001] and −0.008 [*P* = .008], respectively).

Differences in Quality of Care

The measures of quality were inconsistently related to the network measures. An increase in any of the measures (including percent PCPs) generally was associated with worse measures of processes of care, although differences were small (Table 3). These differences were largest for a 1-standard deviation increase in adjusted degree (−1.4% for mammography and −4.3% for LDL testing, both *P* < .001). Readmissions were positively associated with adjusted degree and physician dispersion (increase of 0.5, *P* < .001; and 0.2, *P* = .02, respectively), and were slightly lower for patients of physicians in communities with a higher proportion of PCPs (−0.02, *P* = .03). Preventable (PQI) admissions were slightly higher for patients whose physicians had higher adjusted degree and greater dispersion.

Multivariable Results

Table 4 shows adjusted results that include all 3 network measures applicable to all patients entered into the model. These results are generally consistent with the models limited to 1 network measure at a time.

Discussion

Physicians practice in a social milieu wherein they share patient care with, and are influenced by, other physicians. The extent to which physicians are more widely connected or that patient care is more dispersed may contribute to fragmentation of care and increased costs. Our results support this hypothesis. We find that physicians who share patient care among a larger number of colleagues and those whose patients are dispersed across networks generally exhibit higher spending on health care services. In contrast, patients cared for in networks that are more primary care focused tended to experi-

Table 4. Adjusted Relationship Between Network Characteristics and Medicare Spending, Utilization, and Quality (All Measures Entered Into a Single Model)

		Difference					
Variable	Mean, $	Adjusted Degree	*P* Value	Physician Dispersion	*P* Value	PCP, %	*P* Value
Total spending, $	10 051	1086	<.001	−192	<.001	−62	.33
Spending by category, $							
Hospital inpatient	3533	77	<.001	−15	<.001	0	<.001
Physician	2874	201	<.001	−24	.02	−6	.65
Hospital outpatient department	3526	421	<.001	−81	<.001	−29	.60
Skilled nursing facility							
Hospice	118	1	.14	−2	.04	0	.87
Utilization of services (per patient)							
Admissions	0.38	0.02	<.001	0	.03	0	.87
Hospital days	2.48	0.17	<.001	0.03	.03	−0.02	.42
PCP Office visits	5.53	0.13	.001	−0.07	.02	0.44	<.001
Specialty office visits	6.50	0.38	<.001	−0.04	.07	−0.33	<.001
Emergency department visits	0.64	0.02	<.001	−0.01	<.001	−0.01	.05
Quality of care							
Any 30-day readmission, %	18.3	0.5	<.001	−0.04	.61	−0.10	.09
Acute PQI (per 100)	2.4	0.1	.001	0.1	<.001	0.01	.46
Chronic PQI (per 100)	2.9	0.1	<.001	0.1	.003	0.10	.01
Mammography, %	47.3	−0.7	.001	−2.2	<.001	−1.9	<.001
Diabetes							
LDL cholesterol testing, %	83.1	−2.1	.06	−0.3	.74	0.05	.96
Hemoglobin A_{1c} testing, %	88.0	−1.8	.15	−0.4	.68	−4.6	<.001
Retinal examination, %	60.3	1.8	<.001	−3.0	<.001	−2.2	<.001
All 3 services, %	49.4	1.1	.04	−2.2	<.001	−1.3	<.001
Cardiovascular disease							
LDL testing, %	79.4	−3.6	<.001	−1.6	.02	2.0	.02

Abbreviations: LDL, low-density lipoprotein; PCP, primary care physician; PQI, Prevention Quality Indicators.

ence lower total spending. Quality of care was less strongly associated with these measures.

We previously described physician social networks in the United States and demonstrated how they vary across regions.[26] To our knowledge, the present analysis is the first to show an association between network characteristics and the costs and quality of care on a national scale. These findings suggest that the nature of physician relationships in an area, and an individual's place within the network, could have important influences on care. This might be 1 underlying mechanism explaining some of the observed variations in health care utilization and spending, although the relationships we describe are associations.

Our results also highlight the issue of fragmentation of care. Patients cared for by physicians who share care with a larger number of other physicians and who share across networks, where pertinent patient information is likely to be less routinely available, had higher spending, a finding that was consistent across several different measures. Previously, Pham et al[27] demonstrated the coordination challenge inherent in treating elderly Medicare patients. Our results extend these findings by showing that over and above the absolute number of physicians caring for a patient, what is relevant is the extent to which such physicians, and the patients they care for, are part of a community of physicians with certain care characteristics, such as a predominance of PCPs and more care contained in the community.

Although we did not find a strong association between a community's primary care focus and spending, we did find that patients cared for by physicians in communities with a higher proportion of PCPs had more primary care visits, fewer specialist visits, and fewer emergency department visits. They also had lower spending on hospitalizations. It is not clear why this did not translate into lower overall spending. These findings, however, are similar to evaluations of patient-centered medical home implementation programs, which to date have found inconsistent effects on total spending.

Limitations

These analyses are subject to several limitations. First, we used Medicare data to identify shared patients among physicians. Patterns of patient-sharing may differ for younger patients or patients in Medicare managed care. Second, we based our measure of network connections on shared care for specific episodes of care but it may have undercounted some physician relationships. Moreover, our approach fails to capture physician interactions with other physicians across the country through professional societies and likely underestimates information sharing among physicians in given specialties. Third, our quality measures were limited to measures that could be assessed from administrative claims data. Finally, although we used network measures from the year prior to predict health spending and outcomes in the ensuing calendar year, our primary analyses were cross-sectional in nature and observed associations might not be causal. Similarly, although our models controlled for available sociodemographic and clinical characteristics of patients, unmeasured confounding also could explain some portion of our findings. In addition, the mix of episodes seen in specific geographic areas as well as differences in coding practices could influence the underlying network connections that we discern.

Conclusions

Our findings suggest that characteristics of physician networks, their member physicians, and their patients, may influence care patterns for Medicare patients. Interventions targeted at influential physicians in these networks may have potential to influence care.

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Invited Commentary

Evolving Delivery System and Market Factors and Their Influence on Physician Networks and Patient Care

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In this issue of *JAMA Internal Medicine*, Landon and colleagues[1] apply claims-based algorithms to identify and describe physician networks. Analyzing Medicare data, the authors use pairs of physicians who share patients during specific episodes of care to define distinct networks (called communities) of interconnected physicians. They then investigate whether these networks' characteristics are associated with the cost and quality of care delivered to these physicians' patients. They find that greater numbers of doctors connected to physicians through patient sharing and greater dispersal of patient care outside their physician's network community are associated with increased care costs. Quality measures were not consistently associated with network characteristics, possibly because performance on claims-based process of care measures that were available for study (like diabetes monitoring) do not necessarily capture influences of the broader physician network, as some outcome measures might.

The authors avoid using the term "referral network" in their article, noting simply that physician networks offer opportunities for clinical information exchange. This is understandable because referrals cannot be discerned using claims data, and many Medicare patients self-refer to specialists. But referrals (and informal "curbside consultations" among physicians in referral relationships) are key ways information is exchanged among physicians, and formal referrals likely form the backbone of physician networks. We posit that there are external factors influencing referral networks that may not only influence the network attributes examined in this article, but are likely to independently influence the cost and quality of care for patients served by these networks.

It is easy to understand how referral decisions can affect cost, service utilization, and quality. Specialist referrals are associated with greater utilization and cost and even simple handoffs between physicians impose challenges to efficiency. Although care by specialists may be more guideline concordant,[2] overall quality of care is influenced by myriad factors including the referral's appropriateness, the physician's experience, and the effectiveness of communication between physicians. Shortell and Anderson[3] use exchange theory to describe the transactional nature of physician referrals, explaining that physicians derive dual benefits from referring to high-quality specialists, both to their patients but also to their own expertise and reputation. They may also value specialists who can see their patients soon, provide timely and useful communication around diagnosis and treatment, offer informal consultations not associated with referrals, and are unlikely to assume management of conditions the referring physician feels is within their scope of care. Consulting physicians benefit from the income generated through referrals, the reputation inferred from referrals, and the intrinsic satisfaction from receiving patients with interesting and challenging conditions. This transactional notion of the referral process suggests networks form organically, built on personal relationships and common treatment styles among physicians. As such, attributes of these physician networks—including the prevailing practice styles, specialty orientation, and skills of member physicians—will reflect the values and needs of participating physicians as well as the environments in which they practice. For instance, because uninsured and Medicaid patients often face difficulties accessing specialty care, physicians mostly treating these patients—compared with those treating higher-income insured patients—may need a broad network of consultants willing to see their patients in a timely way rather than prioritizing a network with stellar reputations for quality care.

Other factors influence physician network characteristics. The managed care revolution of the late 1990s and early 2000s spurred concerns that insurer networks constrained referrals of patients to physicians in patients' insurance networks, where health plan criteria for network inclusion need not match those valued by individual physicians choosing consultants.[4] Partially in response to the concerns, HMOs and other health plans retreated from narrow physician networks in the 2000s. The study by Landon et al[1] examines network characteristics formed from physicians treating traditional fee-for-service Medicare patients, for whom there are no limits on referrals. But physicians likely do not maintain unique, separate referral networks that conform to constraints imposed by each patient's insurance coverage, but rather develop a referral network that works for their patient panel overall, one requiring a minimum of fine tuning for individual patients. As such, local insurance market attributes may influence physician network characteristics and performance.

In recent years, other trends have taken on greater salience. Physicians have long been leaving small independent practices for larger single and multispecialty groups; meanwhile hospitals have been purchasing physician groups or