Physician Networks and Ambulatory Care-sensitive Admissions

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Background: Research on the quality and cost of care traditionally focuses on individual physicians or medical groups. Social network theory suggests that the care a patient receives also depends on the network of physicians with whom a patient's physician is connected.

Objectives: The objectives of the study are: (1) identify physician networks; (2) determine whether the rate of ambulatory care-sensitive hospital admissions (ACSAs) varies across networks—even different networks at the same hospital; and (3) determine the relationship between ACSA rates and network characteristics.

Research Design: We identified networks by applying network detection algorithms to Medicare 2008 claims for 987,000 beneficiaries in 5 states. We estimated a fixed-effects model to determine the relationship between networks and ACSAs and a multivariable model to determine the relationship between network characteristics and ACSAs.

Results: We identified 417 networks. Mean size: 129 physicians; range, 26–963. In the fixed-effects model, ACSA rates varied significantly across networks: there was a 46% difference in rates between networks at the 25th and 75th performance percentiles. At 95% of hospitals with admissions from 2 networks, the networks had significantly different ACSA rates; the mean difference was 36% of the mean ACSA rate. Networks with a higher percentage of primary-care physicians and networks in which patients received care from a larger number of physicians had higher ACSA rates.

Conclusions: Physician networks have a relationship with ACSAs that is independent of the physicians in the network. Physician networks could be an important focus for understanding variations in medical care and for intervening to improve care.

Key Words: physician networks, referrals, ambulatory care-sensitive admissions

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Research on the quality and cost of care has traditionally focused on the care provided by individual physicians, medical groups, or hospitals.[1] However, social network theory and recent empirical research suggest that the care a patient receives also depends on the network of physicians with whom that physician is connected.[2–5] The network may affect a patient's care through influencing the way in which physicians practice, through the quality of other physicians to whom the patient may be referred, and through variations in network structure.

In this paper, we attempt to extend the new field of research on physician networks in 3 ways. First, we analyze the performance of "naturally occurring" networks. Previous analyses constrained networks to the physicians associated with a particular hospital[2] or to physicians providing care for patients with a particular diagnosis[4,6]; one paper compared the composition of naturally occurring networks to networks tied to a particular hospital, but did not analyze network performance.[7] Second, this is the first article to test the extent to which individual hospitals receive admissions from >1 network. Third, this is the first article to test whether networks, including networks at the same hospital, vary in their rate of ambulatory care-sensitive hospital admissions (ACSAs)—a policy-relevant outcome variable.

ACSAs are defined by the Agency for Healthcare Research and Quality as admissions for conditions, such as congestive heart failure, for which good primary care may prevent admission.[8] There were >3.9 million ACSAs of adults to US hospitals in 2010, at a cost of $31.9 billion[9]; 40% may have been preventable.[10]

We addressed 2 broad questions. First, we asked whether networks matter: do different networks have different ACSA rates? We hypothesized that networks—even networks that admit to the same hospital—have different

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ACSA rates, after controlling for physician and patient characteristics. Second, we asked whether specific network characteristics are associated with different ACSA rates—in other words, why do networks matter? We hypothesized that networks with a higher percentage of primary-care physicians and/or networks in which primary-care physicians were more central would have lower ACSA rates. This hypothesis was based on research suggesting that primary-care physicians are important for good ambulatory care.[11] We also hypothesized that networks in which patients see large numbers of physicians would have higher ACSA rates. Care coordination may be worse in such networks.[2]

METHODS

Study Population

We identified physician networks in 5 states (Ohio, Pennsylvania, Tennessee, Washington, Wisconsin) in 2008 using Medicare claims data from the Part B and Outpatient files. We studied a random 39% sample of Medicare beneficiaries (987,000 beneficiaries) residing in these states who were 65 years or older, alive at the end of 2008, in the Medicare fee-for-service program for the entire year, and not in the End-Stage Renal Disease program. The 5 states and 39% sample were chosen to obtain reasonable geographic diversity (among and within states) and the maximum number of beneficiaries possible within the 1 million beneficiary budget cut-point for purchasing CMS data.

Eligible Physicians and Services

We excluded anesthesiologists, emergency physicians, hospitalists, pathologists, and radiologists, because physicians in these specialties are likely to work more or less exclusively in the hospital and to see patients without specific referrals from other physicians. We defined hospitalists as physicians who provided >90% of eligible services in the inpatient setting and whose specialty was internal medicine, geriatrics, general practice, or family practice.[12]

We included claims for evaluation and management and surgical services provided by physicians in outpatient settings and for physicians' first visit for a given hospitalization. We excluded claims for imaging and laboratory services.

Appendix 1 (Supplemental Digital Content 1, http://links.lww.com/MLR/A926) provides a flow chart of physician and beneficiary inclusions/exclusions.

Identification of Physician Networks

Figure 1 uses hypothetical data to illustrate how we constructed networks. Any beneficiary who received an eligible service created a tie between each pair of physicians who provided a service to that beneficiary. We coded the value of that tie as the minimum number of times either physician provided a service to that beneficiary. For example, in Figure 1, beneficiary 1 saw physician A 3 times and physician B twice, thus creating a tie between physicians A and B valued at 2 (Figs. 1A, B). We summed these values for individual beneficiaries over all common beneficiaries of each pair of physicians to identify the total strength of the ties—called the "value" of the ties—between the pair (Figs. 1C, D). For example, the sum value of the ties over the beneficiaries whom physician B shared with 3 other physicians had a value of 7, 1, and 4, creating a "valued degree" of 12 for physician B.

The valued degree will be larger for physicians who see many patients,[2] so we adjusted it to create a physician's "adjusted valued degree": the physician's valued degree divided by the number of patients in the network for whom the physician provided at least 1 eligible service. For example, the valued degree for physician B is 12 and physician B's adjusted valued degree is 12/4 = 3 (Fig. 1E).

Physicians A and C have no beneficiaries in common but are connected indirectly through physician B, with whom they both share patients. We found that these indirect links are expansive (Appendix 2, Supplemental Digital Content 2, http://links.lww.com/MLR/A927), and that beneficiaries from the 5 states included in this study created a network of physicians that spanned the United States. This national network is less likely to be important for the day-to-day patient sharing that shapes physician practice, so we focused instead on what we call physician practice communities (PPCs)—smaller networks of physicians who share patients with each other much more often than they share patients with anyone else.

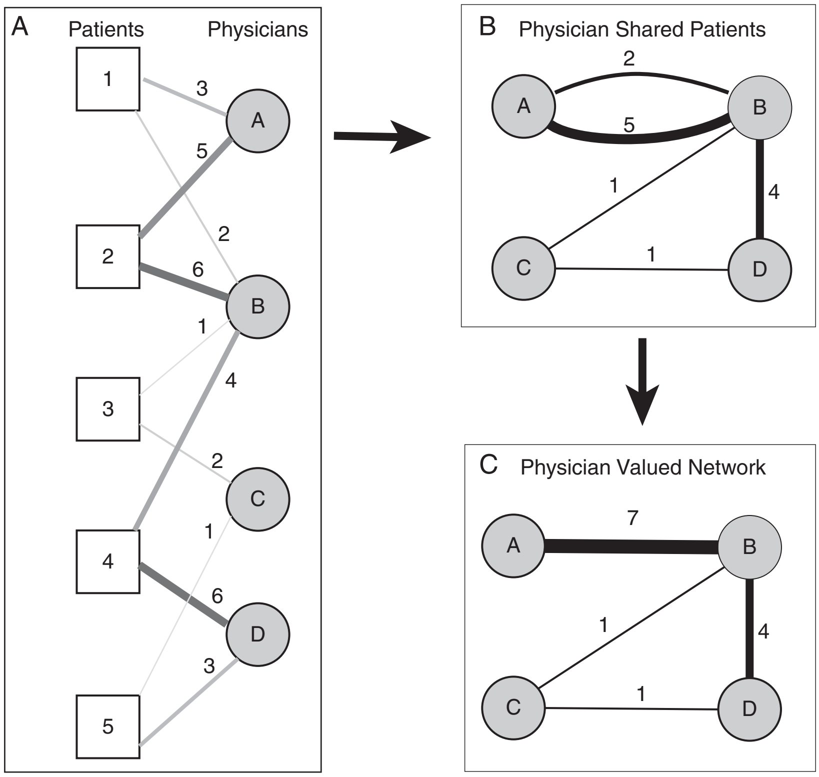
We identified PPCs by using network algorithms designed to identify groups that maximize within-group ties and minimize between-group ties.[13–17] Details are provided in Appendix 2 (Supplemental Digital Content 2, http://links.lww.com/MLR/A927). Figure 2 gives an example from our data of 2 relatively small PPCs that each admitted large numbers of patients to the same hospital. In PPC #1, 85% of the ties (19,330 of 22,755) for the physicians were within the PPC, whereas 15% were with physicians in PPC #2.

Assignment of Medicare Beneficiaries to PPCs and to Physicians

We assigned each beneficiary to the PPC that provided the plurality of eligible services to that beneficiary. For ties, we assigned the beneficiary to the PPC that provided the plurality of evaluation and management visits for that beneficiary; if still tied, beneficiaries were assigned to the PPC in which he or she had the most such visits with primary-care physicians. Once beneficiaries were assigned to a PPC, we assigned them to the physician within that PPC who provided the plurality of claims for that beneficiary, using tie-breakers analogous to those just noted.

Beneficiary Characteristics

We determined beneficiaries' age, sex, race/ethnicity, dual eligibility, and chronic conditions from the Master Beneficiary Annual Summary File. Race was determined using an enhanced race code from the Research Triangle Institute. We used 2000 Census data on per capita income at the ZIP code level as a proxy for beneficiary socioeconomic status.



D Value of ties between physicians by patient

Physicians	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Sum Value
A-B	2	5	0	0	0	7
B-C	0	0	1	0	0	1
B-D	0	0	0	4	0	4
C-D	0	0	0	0	1	1

E Physician Degree

	Degree	Valued Degree	Adjusted Valued Degree
A	1	7	3.5
B	3	12	3
C	2	2	1
D	2	5	2.1

FIGURE 1. Illustration of the construction of a valued physician network from patient visit data. A, How patients create ties among physicians. B, These ties in a simplified format that does not include designated patients. C, The valued ties between each pair of physicians who share patients. D, The value of the ties in tabular rather than graphical format. E, Each physician's degree, valued degree, and adjusted valued degree.

Physician Characteristics

We included physician characteristics that are commonly used as controls or potential indicators of quality (Table 1). We obtained information on physician specialty from the Part B file and on physician demographics and training from the American Medical Association Masterfile.

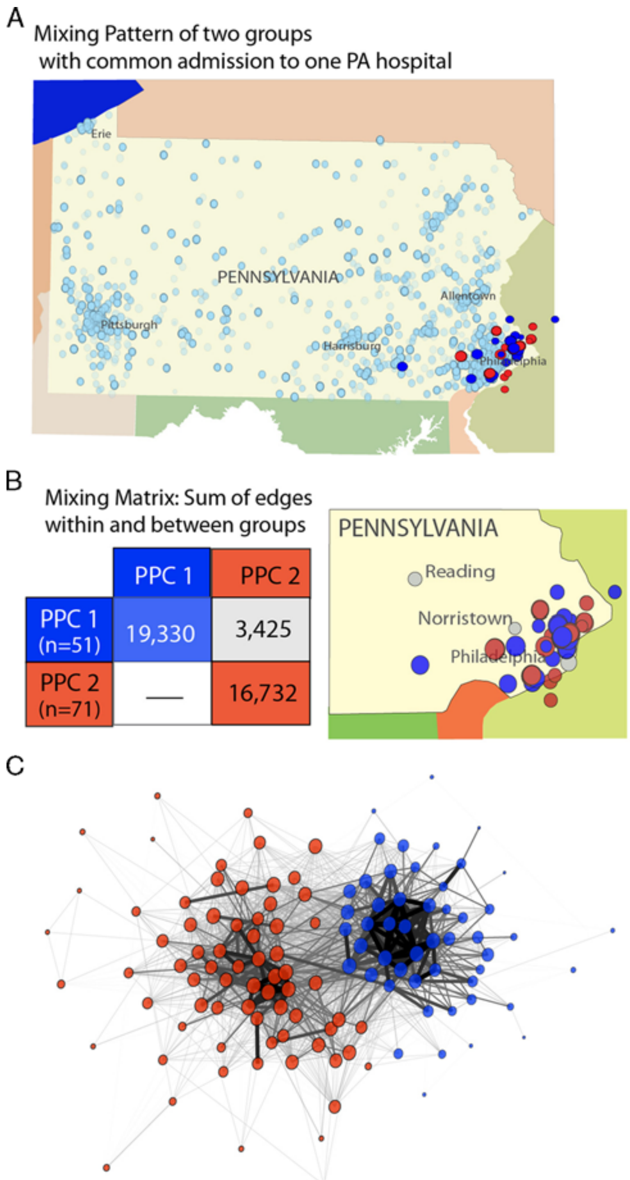


FIGURE 2. Mixing pattern of 2 physician practice communities (PPCs) with common admissions to 1 Pennsylvania hospital. A, All the PPCs for all physicians in Pennsylvania in 2009, highlighting nodes from 2 PPCs. B, The mixing matrix which shows the sum of the ties between physicians within and between the 2 groups and provides a close-up map. C, A sociogram layout based on the distribution of the ties between physicians. Physicians in the "blue" and "red" PPCs have more ties with each other than with physicians in the other PPC.

For each physician, we also calculated 2 measures based on that physician's position within the network: the physician's adjusted valued degree (explained above) and the physician's "betweenness centrality," a standard measure of how central that physician is in the flow of shared patients within the PPC.[18]

PPC-Level Characteristics

For each PPC, we calculated the number of physicians and the percentage of primary-care physicians, physicians who were board-certified, and physicians who were US trained (Table 1). We calculated the percentage of beneficiaries assigned to each PPC who lived in ZIP codes with mean household income of <$30,000 annually. We calculated the mean adjusted valued degree of physicians within the community by summing the total valued degree across all physicians in the community, then dividing by the number of physicians and then by the number of beneficiaries assigned to the community. The hypothetical PPC in Figure 1 has an adjusted valued degree of 1.3 (26 divided by 4 divided by 5). We calculated the "primary care centrality ratio" as the mean betweenness centrality of the primary-care physicians within the community divided by the mean centrality of the specialists within the community.[2]

ACSAs

Using ICD-9-CM diagnosis and procedure codes from the MEDPAR file, we constructed index hospital admissions for 12 ambulatory care-sensitive conditions identified by AHRQ (Appendix 3, Supplemental Digital Content 3, http://links.lww.com/MLR/A928) and counted the number of these admissions for each beneficiary in 2008.[19]

Relationship of PPCs to Individual Hospitals

To determine the extent to which >1 PPC admits patients to the same hospital, we identified all hospitals in the 5 states that were nonteaching hospitals, had at least 100 beds, and had at least 100 admissions in 2008 from the PPCs we identified. Within this set, we identified hospitals that had at least 2 PPCs that each admitted at least 20% of the total number of the hospital's admissions from all our PPCs. We excluded nonteaching hospitals because they draw patients from broad geographic areas and therefore would be expected to have admissions from >1 PPC. We excluded smaller hospitals because we wanted to understand what happens at "typical" community hospitals.

Statistical Analyses

Using the beneficiary as the unit of analysis, we addressed our first question—do networks matter—by estimating a negative binomial model of the relationship between the number of a beneficiary's ACSAs and PPC fixed effects, controlling for patient characteristics. We tested the joint significance of the fixed effects; a statistically significant result would suggest that networks matter. We also used this specification to test whether PPCs that each accounted for at least 20% of admissions to the same hospital differed in their ACSA rates. For each hospital with 2 such PPCs, we compared the fixed-effect coefficients for the 2 communities and used a Wald test to determine whether differences were statistically significant.

To address our second question—why do networks matter?—we replaced PPC fixed-effects with the physician and network characteristics shown in Table 1 to study the relationship between patient, physician, and PPC characteristics and ACSAs. We included state fixed effects. We conducted 3 sensitivity analyses for this model (Appendices 4–6, Supplemental Digital Content 4, http://links.lww.com/MLR/A929 Supplemental Digital Content 5, http://links.lww.com/MLR/A930 Supplemental Digital Content 6, http://

TABLE 1. Descriptive Statistics for Physician Practice Communities and for Beneficiaries and Physicians Assigned to These Communities

	Mean	SD	Minimum	Maximum
Beneficiary characteristics (N = 782,595)				
Age	76.9		65	109
Female (%)	59.4	NA	NA	NA
Dual eligible for at least 1 mo in 2008 (%)	9.4	NA	NA	NA
Race (%)				
White patients	92.8	NA	NA	NA
Black/African American patients	4.8	NA	NA	NA
Hispanic patients	0.9	NA	NA	NA
Asian/Pacific Islander	1.0	NA	NA	NA
American Indian/Alaska Native	0.1	NA	NA	NA
Other race/ethnicity patients	0.4	NA	NA	NA
No. chronic condition warehouse flags per person	3.8	2.556	0	16
Mean ACSA rate per beneficiary	0.06	0.307	0	16
Physician characteristics (N = 54,202)				
US trained (%)	77.3	NA	NA	NA
Female (%)	23.6	NA	NA	NA
Age (%)				
Under 40 y old	29.7	NA	NA	NA
40–50 y old	29.1	NA	NA	NA
50–60 y old	14.7	NA	NA	NA
Over 60 y old	3.9	NA	NA	NA
Board-certified (%)	81.9	NA	NA	NA
Adjusted valued degree	4.42	9.435	0.01	653.00
Betweeness centrality	0.01	0.045	0.00	0.88
Network-level characteristics (N = 386)				
US trained (%)	76.6	10.755	35.4	100.0
Board-certified (%)	80.4	11.434	21.7	100.0
Primary-care physicians in PPC (%)	42.6	11.572	6.3	90.3
Patients living in zip codes with incomes averaging below 30K (%)	10.0	12.486	0.0	68.1
Mean adjusted valued degree	0.13	0.098	0.02	0.97
Betweeness centrality ratio	1.26	1.404	0.00	14.39
No. physicians	169.5	128.700	26.0	963.0

ACSA indicates ambulatory care-sensitive hospital admission; PPC, physician practice community.

links.lww.com/MLR/A931). The first included only beneficiaries who had ≥ 5 chronic illnesses as indicated in the Master Beneficiary Summary—Chronic Conditions File. The second analysis excluded the small number of physicians and PPCs that were extreme outliers (≥ 3 SD from the mean). The third analysis excluded outliers and included only beneficiaries with ≥ 5 chronic illnesses.

We clustered SEs at the level of the PPC. Analyses were conducted using Stata 12.1.

The study was approved by the Institutional Review Boards at Weill Cornell Medical College, the University of Michigan, and Duke University.

RESULTS

We identified 417 PPCs. Their mean size ranged from 128 physicians in Washington to 184 physicians in Ohio; the median size ranged from 98 to 153 (Appendix 7, Supplemental Digital Content 7, http://links.lww.com/MLR/A932 provides additional detail). The mean number of Medicare beneficiaries per PPC was 2002; the median was 1725 (data not shown). As these beneficiaries were a 39% sample of beneficiaries in the Medicare fee-for-service program, the mean number of all beneficiaries in a PPC with a 100% sample would be expected to be 5133. Our analyses were based on 386 PPCs after exclusion of 24 PPCs with <200 beneficiaries and 7 PPCs for technical reasons (Appendix 1, Supplemental Digital Content 1, http://links.lww.com/MLR/A926). The mean percentage of a PPC's patients admitted to the hospital to which the PPC most commonly admitted patients was 58.7% (data not shown). If a PPC is defined as admitting patients to a particular hospital if at least 10% of its admissions went to that hospital, then the average PPC admitted patients to 1.8 hospitals, with the range being 1–5 hospitals (Appendix 8, Supplemental Digital Content 8, http://links.lww.com/MLR/A933 shows data for this and other cut points).

The average beneficiary had 3.8 chronic illnesses and 0.06 ACSAs (Table 1). The range of ACSAs for individual beneficiaries was 0–16; 95.2% of beneficiaries had no ACSA.

The average physician had an adjusted valued degree of 4.42 (Table 1). Betweenness centrality was normalized between 1 and 1; the average physician had scores very near 0, reflecting the high overall connectivity of the PPCs, where most pairs were connected directly or indirectly by short paths.

PPCs varied greatly in the percentage of physicians who were board-certified, attended US medical schools, or were primary care, and in the percentage of patients living in low-income ZIP codes (Table 1). PPCs also varied greatly in the extent to which patients frequently saw multiple physicians:

the mean adjusted valued degree was 0.13 but ranged from 0.02 to 0.97. The mean ratio of the centrality of primary-care physicians to specialists in communities was 1.26, with a range of 0–14.4.

We examined fixed effects for each PPC, controlling for patient and physician characteristics. PPC fixed effects were jointly significant in the model at $P<0.01$, suggesting that PPCs are associated with ACSA rates. The differences in performance were substantial. For example, compared to a mean number of ACSAs of 0.060 per beneficiary per year for all PPCs, the PPC at the 25th percentile of ACSA rates had 0.050 ACSAs per beneficiary, whereas the PPC at the 75th percentile had a 46% higher ACSA rate—0.073 per beneficiary (data not shown).

In multivariable analysis adjusted for patient characteristics and physician age and sex, physicians trained in the United States had significantly lower ACSA rates, as did board-certified physicians (Table 2). The overall mean ACSA rate was 6.02 per hundred patients per year; the rate for US trained physicians was 4.72—21.8% lower than the mean—and for board-certified physicians was 5.70. Physicians who shared patients with other physicians more frequently (ie, physicians whose adjusted valued degree was 1 SD higher than the mean) had significantly more ACSAs—6.79 per hundred patients per year (13.1% higher than the mean ACSA rate), as did physicians who were more central—6.26 ACSAs.

Neither the size of the PPC nor the percentage of US-trained physicians or of board-certified physicians in the PPC was associated with the ACSA rate (Table 2). PPCs with a 1 SD higher percentage of primary-care physicians had a slightly but significantly higher ACSA rate—6.29 per hundred patients per year. PPCs with a higher mean adjusted valued degree—that is, PPCs in which physicians share patients with more other physicians—had a slightly but significantly higher ACSA rate of 6.30 (for PPCs with a degree 1 SD higher than average). The ratio of the centrality of primary-care physicians to the centrality of specialists within PPCs was not associated with the ACSA rate. The results of our 3 sensitivity analyses (Appendices 4–6, Supplemental Digital Content 4, http://links.lww.com/MLR/A929; Supplemental Digital Content 5, http://links.lww.com/MLR/A930; Supplemental Digital Content 6, http://links.lww.com/MLR/A931) were broadly consistent with the results of the main analysis.

We identified 288 hospitals that were nonteaching and had ≥ 100 beds and ≥ 100 admissions of beneficiaries in our database. Thirty-seven (12.8%) of these hospitals had 2 PPCs that each accounted for at least 20% of the hospital's admissions (no hospital had >2 such PPCs). For 35 of the 37 hospitals, the ACSA rates differed between the 2 PPCs at the $P<0.05$ level (Fig. 3). The mean difference in ACSA rates between pairs of PPCs at the same hospital was 2.17 per 100 patients per year, which is equal to 36% of the mean ACSA rate across all PPCs.

DISCUSSION

PPCs matter: networks of physicians who frequently share patients differ significantly in their rates of ACSAs. Everything else being equal, PPCs at the 75th percentile level of performance in terms of ACSA rates had 46% more ACSAs than PPCs at the 25th percentile level. Furthermore, ACSA rates vary greatly even between 2 PPCs that admit patients to the same hospital, even after controlling for patient and physician characteristics. On average, ACSA rates differed by 36% between PPCs that admit to the same hospital.

The largest prior analysis of PPCs identified networks based on physicians who were linked to a single hospital, with 1 network per hospital.[2] Our work suggests that a substantial number of hospitals—although a minority—have >1 network among physicians who admit to a single hospital, and that the performance of networks at the same hospital almost always varies significantly. This suggests that networks should be identified as they naturally occur, without restricting them to individual hospitals—a conclusion supported by recent descriptive research.[7]

Why do PPCs differ in ACSA rates? PPCs vary substantially in size, in the percentage of physicians who were board-certified, the percentage who attended US medical schools, and the percentage of patients living in low-income ZIP codes. However, none of these characteristics were associated with variation in ACSA rates. Contrary to our hypotheses, PPCs with a higher percentage of primary-care physicians had a slightly higher ACSA rate, and PPCs in which primary-care physicians were more central did not vary from other PPCs in their ACSA rate. These results differ from the results of the only relevant prior study, which found that networks in which primary-care physicians were more central had lower overall costs of care for Medicare beneficiaries.[2] The reason for these contradictory results is not clear, but may reflect differences in the methods used for identifying networks and/or the fact that we used ACSAs as the outcome, whereas Barnett and colleagues used total costs.

We found that PPCs in which patients were shared among larger numbers of physicians had slightly but significantly higher ACSA rates. This result was consistent with our hypothesis and consistent with the research of Barnett et al,[2] which found that networks in which patients see more physicians generate higher overall costs for Medicare.

Our study has at least 7 limitations. First, we do not have data on the extent to which physicians within PPCs share patients because they refer them to each other, rather than simply based on patients happening to see the same pairs of physicians. However, prior research found that a high percentage of physicians who are identified as sharing patients based on claims data report that they refer patients to each other.[20] That study was limited to one very large physician organization; further validation studies should be done. However, even when a shared patient is not the result of a referral, physicians who share patients learn what other physicians are doing for the patients, which may influence their practice style. Second, neither our study nor other studies document the extent to which PPCs are simply informal networks of physicians who share patients rather than based on a formal organization such as a medical group. It will be important in future work to determine whether PPCs

TABLE 2. Multivariate Analysis of Variables' Association With Ambulatory Care-sensitive Admissions

Beneficiaries (N = 782,595)	Marginal Effect†	SD	Change in Ambulatory Care-sensitive Admissions per 100 Beneficiaries Per Year‡	Change in Ambulatory Care-sensitive Admissions Per Year as a Percentage of Mean Ambulatory Care-sensitive Admissions Per 100 Beneficiaries Per Year (%)§
Patient-level characteristics				
Age	0.00190***	7.60794	1.45	24.0
Female‖	0.00451***	NA	0.45	7.5
Dual eligible for at least 1 mo in year	0.03570***	NA	3.57	59.5
Race¶				
Black (African American)	0.01423***	NA	1.42	23.7
Hispanic	0.00415	NA	0.42	6.9
Asian/Pacific Islander	−0.01525***	NA	−1.53	−25.4
American Indian/Alaska Native	0.03546**	NA	3.55	59.1
Other race/ethnicity	−0.01320*	NA	−1.32	−22.0
Physician-level characteristics				
US trained#	−0.01305***	NA	−1.31	−21.8
Female4	−0.00274*	NA	−0.27	−4.6
Age**				
40–50 y old	−0.00622***	NA	−0.62	−10.4
50–60 y old	−0.00780***	NA	−0.78	−13.0
>60 y old	−0.01249***	NA	−1.25	−20.8
Board-certified††	−0.00321**	NA	−0.32	−5.4
Adjusted valued degree	0.00310***	2.55319	0.79	13.1
Betweeness centrality	0.03452***	0.07528	0.26	4.3
Network-level characteristics				
US trained physicians in PPC (%)	−0.00012	10.00193	−0.12	−2.0
Board-certified physicians in PPC (%)	−0.00012	9.73159	−0.12	−1.9
Primary-care physicians in PPC (%)	0.00031**	9.19806	0.29	4.7
Patients living in zip codes with incomes averaging <\$30,000 (%)	0.0001	12.28678	0.12	2.0
Nonwhite patients (%)	−0.00004	6.60506	−0.03	−0.4
Mean adjusted valued degree	0.04233***	0.0714	0.30	5.0
Betweeness centrality ratio	−0.00046	0.81118	−0.04	−0.6
Group size in 100s	0.00064	1.4359	0.09	1.5

†The marginal effect is the change in the number of ambulatory care-sensitive admissions per beneficiary per year for a 1 U change in the variable, when the variable is a continuous variable, or for a change from the reference category to the category listed, when the variable is a categorical variable.

‡This is the change in the number of ambulatory care sensitive admissions per 100 beneficiaries per year for a 1 SD change in the variable, when the variable is a continuous variable, or for a change from the reference category to the category listed, when the variable is a categorical variable. For continuous variables, the numbers in this column is the marginal effect multiplied by the SD multiplied by 100.

§The figures in this column = column D divided by the number of ambulatory care-sensitive admissions per year and converted into a percentage. The mean number of ACSA per 100 beneficiaries per year = 6.02

‖Reference group is male.

¶Reference group is white.

#Reference group is non-US trained

**Reference group is <40 years old.

††Reference group is non–board-certified.

*$P<0.10$; **$P<0.05$; ***$P<0.01$.

PPC indicates physician practice community.

based on a formal organization perform differently than PPCs that are informal networks. Third, our analyses show that there is an association between PPCs and certain PPC characteristics and ACSAs; they do not prove causality. Fourth, our study, like other studies of physician networks, is cross-sectional; longitudinal studies would be useful. Fifth, we do not have data on what goes on within the "black box" of PPCs. For example, to what extent do physicians within a given PPC learn from each other and to what extent do they coordinate care for their patients? If PPCs affect the quality and cost of care, to what extent do they do so through their effects on the practice of individual physicians, and to what extent do they do so through effects of the structure of the PPC itself (eg, its size or the centrality of particular physician specialties)? Sixth, we included patients in the traditional Medicare program, not patients from commercial insurers or Medicare Advantage. Seventh, as documented in Appendix 2 (Supplemental Digital Content 2, http://links.lww.com/MLR/A927), many methodological choices must be made when using algorithms to identify PPCs; research will be important to further evaluate the consequences of these choices.

The few studies of physician networks to date suggest a new field of research: the use of network theory and analytic techniques to identify networks and to understand their effects on the quality and cost of health care. Leaders of accountable care organizations, hospitals, large medical groups, and

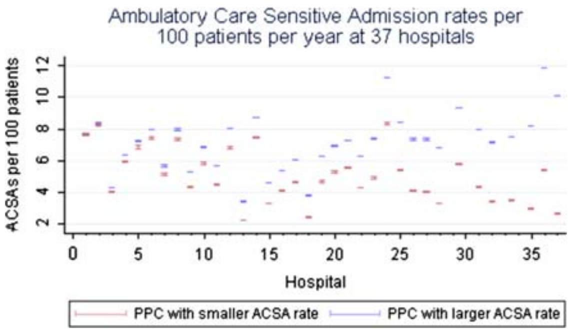


FIGURE 3. Ambulatory care-sensitive hospital admission (ACSA) rates per 100 patients per year at 37 hospitals. The physician practice community (PPC) with the smaller ACSA rate is in red and the PPC with the larger ACSA rate is in blue. The ACSA rate for each of the 2 PPCs admitting to each hospital is displayed on the *y* axis. Each hospital is displayed on the *x* axis. Hospitals are displayed in the order of the smallest to largest difference between the ACSA rates of the 2 PPCs. Each hospital received at least 20% of its total admissions from each of the PPCs. Confidence intervals are provided at the 95% level. When confidence intervals are not visible, this is because they are too narrow to be distinguished in the graph.

independent practice associations might benefit from identifying the different PPCs within their organization. Once these are identified, they could measure the performance of these PPCs, learn from high-performing PPCs, and develop ways to improve the performance of their low-performing PPCs. Leaders of health insurance plans could do the same within the populations of physicians with whom the plan contracts. Physicians—and their patients—might be interested in knowing to which PPC the physician "belongs," who the physicians are in that PPC, and how that PPC performs. The key insight is that the quality and cost of the care a patient receives is likely to depend not only on the individual physician, nor on the hospital or medical group, but also on the network within which the patient's physician is embedded.

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