Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

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Variation in Physician Spending and Association with Patient Outcomes.

eAppendix. Methods

Physician database

Physician characteristics were collected by linking National Provider Identifier (NPI) to a database obtained from Doximity, a company that provides online professional networking services for U.S. physicians. The database included information on age, sex, specialty, years of residency completion, graduated medical schools, and type of medical training (allopathic [MD] versus osteopathic [DO] training). Specialty information in the Doximity database was obtained from multiple sources and data partnerships, including the National Plan and Provider Enumeration System NPI Registry, the American Board of Medical Specialties, other specialty societies, state licensing boards, and collaborating hospitals and medical schools. Descriptions of the database and validation of its accuracy have been published elsewhere.[1-3]

Physician spending

To measure a physician's health care spending level, we used standardized Part B spending, adjusted for patient characteristics and hospital fixed effects. To calculate standardized spending per hospitalization for each physician, we first standardized raw spending using methods established by the Center for Medicare and Medicaid Services (CMS).[4] Doing so accounted for variation in factor prices and malpractice premiums across areas and thus effectively yielded a measure of aggregate health care spending. We then risk-adjusted spending by regressing standardized spending on patient characteristics and hospital fixed effects, using ordinary least squares model. To address outliers, we excluded hospitalizations in the bottom and top 5 percent of residuals, and then refit the regression model on the remaining data. Diagnostics confirmed good fit of the model including linearity, homoscedasticity, and normality. Hospital fixed effects account for differences between hospitals in mean costs of care, including those arising from unobserved differences in patient populations.[5-7]

We calculated an observed-to-expected ratio for each physician by aggregating expected and observed spending over all hospitalizations for a given physician. Multiplying these ratios by the

grand mean of spending per hospitalization yielded a standardized spending level for each physician. Similar methods have been used to estimate physician-level measures in other domains.[8-14]

Identification of hospitalists

Hospitalists are internists who specialize in the care of hospitalized patients. The specialty of hospitalist in the U.S. health system, which began in mid-1990s, is fast emerging; it is estimated that approximately 21,100 to 22,900 hospitalists were practicing in the U.S. in 2010.[15] Hospitalists typically work in scheduled blocks,[16] and therefore, within the same hospital, patients treated by hospitalists may plausibly be quasi-randomized to a given physician based on that physician's work schedule. We used a previously validated definition of hospitalist as general internists with at least 20 evaluation and management (E&M) claims in a given year (equivalent to 5 or more E&M claims in a 5% sample used in the previous study[17]), who filed at least 90% of their total E&M claims in an inpatient setting as defined by Current Procedural Terminology [CPT] codes 99221-99223, 99231-99233, and 99251-99255.[17] This approach had been validated with a high sensitivity (84.2%) specificity (96.5%) and a positive predictive value (88.9%) for identifying hospitalists in the Medicare sample.[17]

eTable 1. *ICD-9 (International Classification of Diseases, 9th Edition)* codes

Condition	ICD-9 codes
Sepsis	0031, 0202, 0223, 0362, 0380, 0381, 03810, 03811, 03812, 03819, 0382, 0383, 03840, 03841, 03842, 03843, 03844, 03849, 0388, 0389, 0545, 449, 77181, 7907, 99591, 99592
Pneumonia	00322, 0203, 0204, 0205, 0212, 0221, 0310, 0391, 0521, 0551, 0730, 0830, 1124, 1140, 1144, 1145, 11505, 11515, 11595, 1304, 1363, 4800, 4801, 4802, 4803, 4808, 4809, 481, 4820, 4821, 4822, 4823, 48230, 48231, 48232, 48239, 4824, 48240, 48241, 48242, 48249, 4828, 48281, 48282, 48283, 48284, 48289, 4829, 483, 4830, 4831, 4838, 4841, 4843, 4845, 4846, 4847, 4848, 485, 486, 5130, 5171
CHF	39891, 4280, 4281, 42820, 42821, 42822, 42823, 42830, 42831, 42832, 42833, 42840, 42841, 42842, 42843, 4289
Urinary tract infection	03284, 59000, 59001, 59010, 59011, 5902, 5903, 59080, 59081, 5909, 5950, 5951, 5952, 5953, 5954, 59581, 59582, 59589, 5959, 5970, 59780, 59781, 59789, 59800, 59801, 5990
COPD	490, 4910, 4911, 4912, 49120, 49121, 49122, 4918, 4919, 4920, 4928, 494, 4940, 4941, 496

Abbreviations: CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease.

eTable 2. Proportion of variation in adjusted Medicare spending explained by hospitals, physicians, and patients

	Variation	Total spending	Part B spending	Evaluation & management spending
General internists	Variance partition coefficients (VPCs), %			
	Between hospitals	1.7%	6.2%	6.7%
	Between physicians	11.6%	10.5%	10.9%
	Between patients	86.7%	83.3%	82.4%
	Inter-unit reliability (IUR)	0.78	0.77	0.77
Hospitalist physicians	Variance partition coefficients (VPCs), %			
	Between hospitals	2.0%	7.0%	7.6%
	Between physicians	9.2%	8.4%	8.8%
	Between patients	88.8%	84.5%	83.6%
	Inter-unit reliability (IUR)	0.74	0.73	0.74

General internists include both hospitalist and non-hospitalist internists.

Total spending is defined as the sum of Part A spending and Part B spending for a given hospitalization.

eTable 3. Adjusted association between physician spending and 30-day patient outcomes, using total spending (Part A spending + Part B spending) for calculating physician spending

		No. of hospitalizations (No. of physicians)	Adjusted odds ratio* (95%CI)	p-value
30-day mortality rate	Model 1: Adjusted for patient characteristics and hospital fixed effects	346,177 (13,833)	**0.99** (0.98 to 1.00)	0.054
	Model 2: Model 1 + physician characteristics	277,586 (11,120)	**0.99** (0.98 to 1.01)	0.41
30-day readmission rate	Model 1: Adjusted for patient characteristics and hospital fixed effects	341,811 (13,876)	**1.00** (0.99 to 1.01)	0.64
	Model 2: Model 1 + physician characteristics	274,372 (11,171)	**1.00** (0.99 to 1.01)	0.53

*For every $100 increase in physicians' adjusted spending level.

Patient characteristics include age, sex, race, MS-DRG, 27 coexisting conditions, median household income, an indicator for Medicaid coverage, and indicators for year. Physician characteristic include age, sex, medical school graduated from, and type of medical training (MD/DO).

eTable 4. Adjusted association between physician spending and 30-day patient outcomes, using alternative method for attributing physicians to patients

			No. of hospitalizations (No. of physicians)	Adjusted odds ratio* (95%CI)	p-value
30-day mortality rate	Largest number of E&M claims	Model 1: Adjusted for patient characteristics and hospital fixed effects	328,078 (12,472)	**0.99** (0.98 to 1.00)	0.06
		Model 2: Model 1 + physician characteristics	263,328 (10,035)	**0.99** (0.98 to 1.01)	0.23
	First E&M claim	Model 1: Adjusted for patient characteristics and hospital fixed effects	318,242 (12,273)	**0.99** (0.97 to 1.00)	0.04
		Model 2: Model 1 + physician characteristics	253,074 (9,879)	**0.99** (0.98 to 1.01)	0.30
30-day readmission rate	Largest number of E&M claims	Model 1: Adjusted for patient characteristics and hospital fixed effects	323,920 (12,505)	**1.00** (0.99 to 1.01)	0.40
		Model 2: Model 1 + physician characteristics	260,257 (10,077)	**1.00** (0.99 to 1.01)	0.75
	First E&M claim	Model 1: Adjusted for patient characteristics and hospital fixed effects	313,886 (12,310)	**1.00** (0.99 to 1.01)	0.76
		Model 2: Model 1 + physician characteristics	252,763 (9,919)	**1.00** (0.98 to 1.01)	0.43

Physicians who accounted for the largest number of E&M claims, or who accounted for the first E&M claim, were assigned as the primary attending physician.

*For every $100 increase in physicians' adjusted spending level.

eTable 5. Adjusted association between physician spending and 30-day patient outcomes, trimming observations with top and bottom 3 or 7 percentiles of residuals

			No. of hospitalizations (No. of physicians)	Adjusted odds ratio* (95%CI)	p-value
30-day mortality rate	Trim top & bottom 3%	Model 1: Adjusted for patient characteristics and hospital fixed effects	350,524 (14,136)	**0.99** (0.98 to 1.01)	0.29
		Model 2: Model 1 + physician characteristics	280,699 (11,348)	**1.00** (0.99 to 1.01)	0.85
	Trim top & bottom 7%	Model 1: Adjusted for patient characteristics and hospital fixed effects	342,400 (13,521)	**0.98** (0.97 to 1.00)	0.01
		Model 2: Model 1 + physician characteristics	274,497 (10,862)	**0.99** (0.97 to 1.00)	0.13
30-day readmission rate	Trim top & bottom 3%	Model 1: Adjusted for patient characteristics and hospital fixed effects	345,812 (14,168)	**1.00** (0.99 to 1.01)	0.96
		Model 2: Model 1 + physician characteristics	277,277 (11,395)	**1.00** (0.99 to 1.01)	0.81
	Trim top & bottom 7%	Model 1: Adjusted for patient characteristics and hospital fixed effects	338,005 (13,564)	**1.00** (0.99 to 1.01)	0.72
		Model 2: Model 1 + physician characteristics	271,281 (10,915)	**1.00** (0.98 to 1.01)	0.51

*For every $100 increase in physicians' adjusted spending level.

Patient characteristics include age, sex, race, MS-DRG, 27 coexisting conditions, median household income, an indicator for Medicaid coverage, and indicators for year. Physician characteristic include age, sex, medical school graduated from, and type of medical training (MD/DO).

eTable 6. Adjusted association between physician spending and 30-day patient outcomes, restricting to physicians with 30 or more hospitalizations in 2011-2012

		No. of hospitalizations (No. of physicians)	Adjusted odds ratio* (95%CI)	p-value
30-day mortality rate	Model 1: Adjusted for patient characteristics and hospital fixed effects	176,869 (4,817)	**0.98** (0.96 to 1.00)	0.12
	Model 2: Model 1 + physician characteristics	143,315 (3,909)	**0.99** (0.96 to 1.01)	0.26
30-day readmission rate	Model 1: Adjusted for patient characteristics and hospital fixed effects	174,316 (4,827)	**0.99** (0.97 to 1.01)	0.24
	Model 2: Model 1 + physician characteristics	141,585 (3,920)	**0.99** (0.97 to 1.01)	0.21

*For every $100 increase in physicians' adjusted spending level.

Patient characteristics include age, sex, race, MS-DRG, 27 coexisting conditions, median household income, an indicator for Medicaid coverage, and indicators for year. Physician characteristic include age, sex, medical school graduated from, and type of medical training (MD/DO).

eTable 7. Adjusted association between physician spending and 30-day patient outcomes, including patients who were transferred out

		No. of hospitalizations (No. of physicians)	Adjusted odds ratio* (95%CI)	p-value
30-day mortality rate	Model 1: Adjusted for patient characteristics and hospital fixed effects	346,672 (13,834)	**0.99** (0.98 to 1.00)	0.09
	Model 2: Model 1 + physician characteristics	277,788 (11,112)	**1.00** (0.98 to 1.01)	0.48
30-day readmission rate	Model 1: Adjusted for patient characteristics and hospital fixed effects	342,054 (13,870)	**1.00** (0.99 to 1.01)	0.93
	Model 2: Model 1 + physician characteristics	274,406 (11,158)	**1.00** (0.99 to 1.01)	0.54

*For every $100 increase in physicians' adjusted spending level.

Patient characteristics include age, sex, race, MS-DRG, 27 coexisting conditions, median household income, an indicator for Medicaid coverage, and indicators for year. Physician characteristic include age, sex, medical school graduated from, and type of medical training (MD/DO).

eTable 8. Adjusted association between physician spending and 30-day patient outcomes, after excluding patients with cancer and patients who were discharged to hospice

		No. of hospitalizations (No. of physicians)	Adjusted odds ratio* (95%CI)	p-value
30-day mortality rate	Model 1: Adjusted for patient characteristics and hospital fixed effects	305,720 (13,727)	**0.99** (0.97 to 1.00)	0.11
	Model 2: Model 1 + physician characteristics	244,271 (11,001)	**0.99** (0.98 to 1.01)	0.54
30-day readmission rate	Model 1: Adjusted for patient characteristics and hospital fixed effects	304,623 (13,827)	**1.00** (0.99 to 1.01)	0.77
	Model 2: Model 1 + physician characteristics	244,381 (11,116)	**1.00** (0.98 to 1.01)	0.39

*For every $100 increase in physicians' adjusted spending level.

Patient characteristics include age, sex, race, MS-DRG, 27 coexisting conditions, median household income, an indicator for Medicaid coverage, and indicators for year. Physician characteristic include age, sex, medical school graduated from, and type of medical training (MD/DO).

eTable 9. Adjusted association between physician spending and 30-day patient outcomes, additional adjustment for length of stay

		No. of hospitalizations (No. of physicians)	Adjusted odds ratio* (95%CI)	p-value
30-day mortality rate	Model 1: Adjusted for patient characteristics and hospital fixed effects	348,387 (13,916)	**1.00** (0.99 to 1.01)	0.68
	Model 2: Model 1 + physician characteristics	279,964 (11,207)	**1.00** (0.99 to 1.02)	0.62
30-day readmission rate	Model 1: Adjusted for patient characteristics and hospital fixed effects	343,827 (13,953)	**0.99** (0.98 to 0.99)	0.01
	Model 2: Model 1 + physician characteristics	276,462 (11,252)	**0.99** (0.98 to 0.99)	0.01

*For every $100 increase in physicians' adjusted spending level.

Patient characteristics include age, sex, race, MS-DRG, 27 coexisting conditions, median household income, an indicator for Medicaid coverage, and indicators for year. Physician characteristic include age, sex, medical school graduated from, and type of medical training (MD/DO).

eTable 10. Adjusted association between physician spending and 30-day patient outcomes, among general internists

		No. of hospitalizations (No. of physicians)	Adjusted odds ratio* (95%CI)	p-value
30-day mortality rate	Model 1: Adjusted for patient characteristics and hospital fixed effects	547,056 (23,761)	**1.01** (1.00 to 1.01)	0.24
	Model 2: Model 1 + physician characteristics	446,192 (19,547)	**1.01** (1.00 to 1.01)	0.30
30-day readmission rate	Model 1: Adjusted for patient characteristics and hospital fixed effects	535,033 (23,769)	**1.00** (1.00 to 1.01)	0.23
	Model 2: Model 1 + physician characteristics	436,549 (19,556)	**1.00** (0.99 to 1.01)	0.67

*For every $100 increase in physicians' adjusted spending level.

Patient characteristics include age, sex, race, MS-DRG, 27 coexisting conditions, median household income, an indicator for Medicaid coverage, and indicators for year. Physician characteristic include age, sex, medical school graduated from, and type of medical training (MD/DO).

eTable 11. Adjusted association between physician spending and 30-day patient outcomes, stratified by primary diagnosis

	Primary diagnosis	No. of hospitalizations (No. of physicians)	Adjusted odds ratio* (95%CI)	p-value
30-day mortality rate	Sepsis	27,927 (7,819)	**1.02** (0.99 to 1.05)	0.27
	Pneumonia	14,773 (5,463)	**1.02** (0.96 to 1.08)	0.57
	CHF	15,992 (5,901)	**0.99** (0.95 to 1.04)	0.81
	Urinary tract infection	7,154 (3,252)	**1.02** (0.93 to 1.11)	0.68
	COPD	5,510 (2,428)	**1.09** (0.98 to 1.20)	0.10
30-day readmission rate	Sepsis	24,130 (7,115)	**1.04** (1.00 to 1.07)	0.03
	Pneumonia	16,158 (6,099)	**0.99** (0.95 to 1.04)	0.77
	CHF	17,884 (6,710)	**1.01** (0.98 to 1.05)	0.56
	Urinary tract infection	11,096 (5,002)	**1.00** (0.95 to 1.05)	0.93
	COPD	10,530 (4,757)	**0.97** (0.93 to 1.02)	0.26

Abbreviations: CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease.

*For every $100 increase in physicians' adjusted spending level.

Adjusted for patient and physicians characteristics and hospital fixed effects (Model 2).

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