DR. ADRIAN DIAZ (Orcid ID : 0000-0002-6011-374X)

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Variation in Surgical Spending within Hospital Systems for Complex Cancer Surgery

Adrian Diaz MD MPH[1,4,5], Karan R. Chhabra MD MSc[2,4,5], Justin B. Dimick MD MPH[3,5], Hari Nathan MD PhD[3,5]

[1]The Ohio State University, Department of Surgery, Columbus, OH
[2]Brigham And Women's Hospital, Department of Surgery, Boston, MA, USA
[3]University Of Michigan, Department of Surgery, Ann Arbor, MI, USA
[4]University Of Michigan, IHPI Clinician Scholars Program, Ann Arbor, MI, USA
[5]University Of Michigan, Center for Healthcare Outcomes and Policy, Ann Arbor, MI, USA

Corresponding author:
Adrian Diaz, MD MPH
Adriandi@med.umich.edu
2800 Plymouth Road
Building 14, Room G100
Ann Arbor, MI 48109
786.543.8436 (c)
734.647.3301 (f)

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Precis: Despite an opportunity for health systems to standardize care and reduce inefficiencies, we found wide variation in surgical episode spending both across and within systems among Medicare beneficiaries undergoing a complex cancer operation. Surgeons and system leaders may seek to better understand variation in practices between their hospitals in order to standardize care and reduce variation in outcomes, utilization, and costs.

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Abstract

Background: Seventy percent of hospitals today are part of larger health systems. Proponents of hospital consolidation tout its potential to reduce health spending and improve outcomes, but available evidence suggests this promise is unrealized. Variation in costs and outcomes *within systems* may highlight opportunities for collaborative quality improvement and practice standardization. To assess this potential, we sought to measure variation in episode spending within and across hospital systems among Medicare beneficiaries undergoing complex cancer surgery.

Methods: Using 100% Medicare claims data, we identified fee-for-service Medicare patients undergoing elective pancreatectomy, lung resection, or colectomy for cancer from 2014-2016. We calculated risk-adjusted, price-standardized payments for the surgical episode from admission through 30 days post discharge. We then assessed the reliability-adjusted variation at hospital and system levels.

Results: Average episode payments varied nearly as much within hospital systems for pancreatectomy ($1,946 between the lowest and highest-spending systems, 95% CI $1,910 to $1,972), lung resection ($625, 95% CI $621 to $630), and colectomy ($813, 95% CI $809 to $817) as they did between the lowest- and highest-spending hospitals (Pancreatectomy:$2,034, Lung Resection $1,789, Colectomy: $770). For pancreatectomy, variation was driven by index hospitalization spending whereas both index hospitalization and post-acute care utilization drove variation for lung and colon resection.

Conclusion: In this analysis of Medicare patients undergoing complex cancer surgery, we found wide variation in surgical episode spending both within and across hospital systems. System leaders may seek to better understand variation in practices among their hospitals in order to standardize care and reduce variation in outcomes, utilization, and costs.

Introduction

The accelerating pace of hospital consolidation over the last two decades has resulted in 70% of hospitals today belonging to larger health systems.[1,2] Proponents of hospital mergers tout their potential to improve outcomes and reduce health spending by standardizing care, eliminating redundancy, and achieving economies of scale.[3] However, there is conflicting evidence as to whether expanding hospital systems are reducing health spending.[4–7] Furthermore, wide variation in surgical episode expenditures within health systems has been observed.[8,9] These observations call into question whether systems are leveraging their collective volume and experience to standardize care and maximize efficiencies If care patterns within a health system vary significantly, this suggests that the system may have failed to address gaps in practice standardization and clinical quality across its affiliated hospitals.[9]

Because cancer care can be high-risk and often multidisciplinary, it may lend itself well to being optimized through hospital consolidation. Many systems have taken the first step of using their expanding referral networks to concentrate volumes and improve quality within these service lines. However, inconsistencies in quality may persist. Recent research has shown that for hospitals performing hip replacement, discharge patterns vary nearly as much within systems as between systems, indicating that inconsistencies in care coordination persist within systems.[8] Variation in surgical expenditures, which can be reliably measured, is a useful marker for understanding the degree of standardization of surgical quality and care pathways. For example, systems may control episode spending by internally referring patients to their lowest-spending hospitals or disseminating low-cost centers' care patterns throughout their affiliates.[10] However, whether systems are actually leveraging their position to reduce variation in surgical episode spending for high-risk cancer surgery remains unknown.

In this study, we explored surgical spending variation within and across hospital systems in the United States using Medicare data on patients undergoing pancreas, lung, or colon resection for cancer. We chose these procedures because they range in both frequency and complexity. We hypothesized significant variation in surgical episode spending on high-risk cancer operations both within and across health systems.

Methods

Data Source and Population

We used 100% claims from the Medicare Provider Analysis and Review (MedPAR) file for cancer resections from calendar years 2014-2016 at nonfederal acute care hospitals. We used procedure codes for colon resection, lung resection and pancreas resection from the International Classification of Diseases, Version 9 and 10 Procedure Coding System from the MedPAR file, with confirmatory current procedural terminology codes from the Medicare Carrier File, to define the cohort. We included fee-for-service Medicare patients aged 66–99 years with continuous coverage for 3 months before and 6 months after the surgical procedure of interest. We excluded nonelective admissions, hospitals with <10 fee-for-service Medicare cases across all three years, hospitals not participating in systems, and patients in Medicare Advantage. We additionally excluded any systems with fewer than 2 hospitals represented in our cohort. Hospital identifiers from the MedPAR file were linked to the American Hospital Association (AHA) Annual Survey for each corresponding year, which provided system identifiers and hospital characteristics.

Outcomes

Our primary outcomes were Medicare's 30-day episode payments ("spending"), with specific attention to the total episode payment, index hospitalization and post-acute care component of the total payment. These were derived from the MEDPAR, carrier, outpatient, and home health agency files. ''Episodes'' encompassed the index procedure with associated hospitalization and post-acute care services, physician services, readmissions, and outpatient care up to 30 days after discharge. We defined ''institutional post-acute care'' as discharge to a facility for skilled nursing, inpatient rehabilitation, intermediate care, or long- term care.[11] We used price-standardization methods previously described to adjust for intended differences in Medicare payment rates (by year, wage index, and graduate medical education expenses).[12–15] Additionally, we provide more detailed methodology on our price standardization in appendix 1.

Definitions

Because centralizing surgical volume at the highest-value centers is one potential strategy for minimizing variation and improving outcomes, we measured procedural volume at each system's hub relative to the system as a whole. We identified ''hubs'' as the hospitals with the highest Medicare volume for each procedure within each system. We calculated volume ''concentration'' by dividing the hub's case volume by the total system case volume for each procedure, for each system.[16]

Analysis

Patient-level episode payments were winsorized to the 1st and 99th percentiles to limit the influence of extreme outliers. Winsorization recodes extreme outliers to less extreme values, improving model fit while preserving the underlying signal and without deleting observations.[17] Our use of winsorization does not remove extreme values—rather, it resets them to less extreme values. Thus, very extreme outliers (e.g. payments at the 99.9th percentile) will be reset to the 99th percentile, and hospitals with many extreme outliers will continue to have higher average payments despite winsorization. Outliers were equally present at the high and low end of the distribution. Winsorization occurred after price-standardization. Overall 2.0% of the data was winsorized (pancreas:1.9%, lung:2.0%; colon:2.0%). We then fit multilevel linear regression models with hospital- and system-level random effects to estimate average total episode payments. Risk adjustment controlled for patient age (as a quadratic term), sex, and Elixhauser comorbidities. In addition to this, we adjusted for International Classification of Diseases, Version 9 and 10 principal diagnosis and procedure codes (as indicator variables) to capture differences in patient condition and surgical approach.

Then, we used the models to calculate risk- and reliability- adjusted average payments at the hospital and system-level. Reliability adjustment was utilized to reduce statistical "noise" and create more accurate hospital rankings.[18,19] This technique filters out statistical "noise" by shrinking the observed rate toward the average rate. This problem can be conceptualized by imagining a hospital with a mortality rate of 0, but only 5 cases. It is highly likely that, if the hospital were to do 100 more cases, the mortality would no longer be zero. Reliability uses hierarchical modeling techniques adjust estimates based on sample size variation, so that deviations from average are much more likely to represent true deviations rather than statistical noise.

For this study, we used a 2-level model with the hospital as the first-level and the system as the second-level. Using postestimation commands, we created empirical Bayes estimates of each hospital's and system's random effect. These random effects represent the risk-adjusted and reliability-adjusted "signal." Models treating random effects as independent, exchangeable, and unstructured were compared and no differences noted in the outcomes. In the final model random effects were treated independently as it was unlikely that hospitals within a system were coordinating with one another in a meaningful way based on our hypothesis.

We calculated hospital average spending by adding the national average total episode payment to the hospital's and relevant system's best linear unbiased predictors. We calculated system average spending by adding the national average total episode payment to the best linear unbiased predictor of the system's random effect. These risk- and reliability- adjusted estimates were used to divide systems into quintiles of average spending, weighted at the episode level. Payment variation within systems was calculated by comparing the highest-spending and lowest-spending hospital's risk- and reliability-adjusted averages.

Postoperative outcomes and discharge destination risk-adjusted rates were derived using marginal means in logistic regression models in which the outcome was treated as a categorical variable. All models were adjusted for patient age, sex, race, and 27 Elixhauser comorbidities, overall time trends, and hospital characteristics. In addition to this, we adjusted for International Classification of Diseases, Version 9 and 10 principal diagnosis and procedure codes (as indicator variables) to capture differences in patient condition and surgical approach. All outcomes and discharge destination are reported as risk-adjusted rates.

All analyses were performed in Stata 16 (College Station, TX). This study was deemed exempt by the University of Michigan institutional review board.

Results

Hospital and system characteristics

We identified 57,458 Medicare patients who underwent either pancreas, lung, or colon resection from 2014 to 2016 (Table 1). For pancreatectomy, 5,415 episodes occurred at 322 hospitals within 95 systems. Average total episode payments ranged from $31,481 (1st quintile) to $33,427 (5th quintile) across systems. For lung resection, 23,285 episodes occurred at 563 hospitals within 111 systems. Average total episode payments ranged from $20,700 to $21,325 across systems. For colectomy, 28,849 episodes occurred at 990 hospitals within 160 systems. Average total episode payments ranged from $18,417 to $19,513 across systems. For each operation, patients' age, sex, race, and Elixhauser comorbidity counts were similar across all quintiles. Mean number of hospitals per system ranged from ten for pancreatectomy to 17 for colectomy. For each operation, the percent of patients treated at a for-profit hospital was highest in the highest-spending quintile.

Although procedures were analyzed independently there were hospitals and hospital systems that were low cost for more than one procedure. Specifically, 40 hospitals had lower than mean spending for all three procedures studied and 90 hospitals had lower than mean spending for two of the three procedures. Among hospital systems, 49 had lower than mean spending for all three procedures and 99 had lower than mean spending for two of the three procedures.

Across-system variation

The difference in total episode payments for pancreatectomy between the lowest and highest-spending quintiles of systems was $1,946 (95% CI $1,910 to $1,972), or 6.2% of total episode spending in the lowest quintile (Figure 1). The largest component of this variation (39%) was accounted for by index hospitalization spending, followed by post-acute care spending (27%) (Table 2). The lowest-spending quintile had an average risk-adjusted serious complication rate of 8.6% compared to 15.9% ($p < 0.001$) in the highest-spending quintile. Fewer patients were discharged home in the highest-spending versus lowest-spending quintile (34% versus 45%) (Table 3).

The difference in total episode payments for lung resection between the lowest and highest-spending quintiles of systems was $625 (95% CI $621 to $630), or 3.0% of total episode spending in the lowest-spending quintile (Figure 2). For colectomy this difference was $813 (95% CI$809 to $817), or 4.4% of total episode spending in the lowest-spending quintile. Notably, for 39 systems (24.4%), every hospital had higher average episode spending than the national average (figure3). For both operations, post-acute care spending explained the largest component of the variation in spending (37% for lung and 47% for colon), followed by index hospitalization payments. For lung resection the highest-spending systems discharged 54% of patients home, compared to 63% in the lowest-spending systems. Similarly, for colectomy the highest-spending systems discharged 66% of patients home, compared to 61% in the lowest-spending systems. There was no difference in postoperative complications, mortality or readmissions related to episode spending between the lowest- and highest quintiles for lung resection. However, for colon resection, postoperative complications were 1.8% higher in the highest-spending versus lowest-spending quintile. This difference in quality may have contributed to the 15% variation in index hospitalization spending and the 25% variation in physician payment variation (Table3).

Average total episode spending at the hubs of the lowest spending systems was lower than spending at the hubs of the highest-spending system (table 4). For pancreatectomy spending was $5,349 less at the hubs of the lowest spending systems compared to the hubs of the highest-spending systems. Furthermore, case volume (174 vs 64), concentration (85% vs 64%), and hospital beds (1027 vs 591) were all greater at the hubs of the lowest-spending systems compared to the hubs of the highest-spending systems (all $p < 0.001$). Finally, hubs from the lowest-cost systems discharged patients home at a higher rate than hubs from the highest-cost systems (48% vs. 28%, $p < 0.001$).

For lung resection and colon resection spending was $2,833 and $1,498 less at the hubs of the lowest spending systems compared to the hubs of the highest-spending systems. Contrary patterns observed for pancreatectomy, case volume, concentration, and hospital beds were either lower or not different at the hubs in the lowest-spending system compared to the hubs of the highest-spending systems (table 4). hubs from the lowest-cost systems discharged patients home at a higher rate than hubs from the highest-cost systems (Lung:69% vs. 41%; Colon: 69% vs 56% ; both $p < 0.001$).

Within-system variation

Risk- and reliability-adjusted episode payment variation for all three operations was greater within systems than across systems (Table 2). The variation between the lowest- and highest-spending hospitals within a system was on average $2,034 (interquintile range $772 to $5,682) for pancreatectomy, $1,789 (interquintile range $465 to $4,305) for lung resection, and $770 (interquintile range $211 to $1,575) for colectomy. The index hospitalization spending largely explained the within-system variation in hospital spending for all three operations. Of note, greater variation between lowest- and highest-spending hospital within the system was associated with modestly higher system average total episode payment.

Case concentration

Average case concentration at the system hub ranged from 47% for colectomy to 76% for pancreatectomy. Greater concentration was associated with lower spending for pancreatectomy. Pancreatectomy case concentration ranged from 82% in the lowest-spending quintile to 63% in the highest-spending quintile. There was a difference of $934 (95% CI $932 to $935) between the least- and most-centralized systems (Appendix1). For colectomy on the other hand, case concentration varied from 42% to 53% but with no systematic variation across quintiles of spending (Table 1). There was only a difference of $80 (95% CI $79 to $81) between the leastand most-centralized systems. Similar findings were observed for lung resection: there was only a difference of $104 (95% CI $104 to $110) between the least- and most-centralized systems.

Discussion

Proponents of hospital consolidation highlight its potential to reduce health spending by standardizing care, eliminating redundancy, and achieving economies of scale. Whether these advantages have been realized for patients, payers, and the systems themselves is unknown. Variation in surgical expenditures is one measurable indicator of the degree of quality and care standardization achieved by a system. We would expect that well-functioning systems should both reduce average expenditures and reduce the variation in expenditures within their systems. Furthermore, because complications, quality of care, and care coordination are often correlated with costs of care,[21–23] variation in spending within and across systems may signal opportunities for quality improvement. In this analysis, among Medicare beneficiaries undergoing oncologic pancreas, lung, or colon resection we observed significant variation in surgical episode spending both within and across hospital systems. The degree of within-system variation, as compared to the across-system variation, may reflect the degree to which hospital systems have standardized care in particular service lines.

For the cancer resection procedures studied, there was modest variation in spending between systems, ranging from 3.0% for lung resection to 6.2% for pancreatectomy. Given the number of procedures performed, however, the aggregate expenditures associated with such variation are significant. For comparison, CMS's bundled payment programs including the Acute Care Episode Demonstration, the voluntary Bundled Payments for Care Improvement initiative, and the mandatory Comprehensive Care for Joint Replacement model have yielded mixed results ranging from no change in spending to 3.9% savings for select episodes such as joint replacement.[24,25] With that in mind, the variations in surgical episode spending observed within and across hospitals systems present sizable opportunities for system leaders to realize significant savings, comparable to those achieved by large-scale alternative payment models.

For pancreatectomy, variation both within and across systems was driven by index hospitalization payments. Additionally, the lowest-spending systems had significantly lower postoperative complication rates compared to the highest-spending systems. Increased centralization of pancreatectomy was associated with lower spending and better quality, as we have previously reported.[16] These findings suggest one strategy that systems may use to optimize outcomes and costs of complex, less common operations, such as pancreatectomy: centralize volume and focus quality improvement efforts at one or a few referral centers. This strategy is consistent with the robust literature documenting volume-outcome relationships for complex surgical procedures[26–29], but implementation of volume-based referral within a hospital system avoids the disincentive of lost revenue that may otherwise prevent low-volume hospitals from turning away such cases.[30]

Similarly, for more common procedures such as lung and colon resection, variation within systems was driven by index hospitalization payments, suggesting that hospitals within the same system have significant differences in utilization patterns even around the same operation—likely relating to differences in practice patterns, complication rates, or both. For both procedures, however, variation across systems was dominated by differences in post-acute care payments. Although complication rates and index hospitalization payments did vary significantly across systems, the relatively larger variation in post-acute care payments suggests that optimizing discharge destination may be an opportunity to control spending. For example, our group has shown that for hospitals performing hip replacement, discharge patterns varied nearly as much within systems as they did across systems, attributing to 86% of spending variation between lowest and highest cost systems.[10] This variation in discharge destination after joint replacement is commonly thought to be due to idiosyncratic provider preferences, rather than unmeasured differences among patients. Though it is not well-studied, variation in post-acute care utilization after cancer resection may be similarly discretionary. In these instances, where operations are commonly performed at various affiliated hospitals within a system, surgeons and hospital leaders have an opportunity to standardize best practices across the health system. In this study, we observe similar discharge patterns among lung and colon resection. As such, interventions aimed as standardizing care such as enhanced recovery after surgery (ERAS) protocol and reduction in post-acute care utilization have not only improved quality but reduced cost.[31–33] Furthermore, for colectomy, nearly a quarter of systems had all of their hospitals with average episode payments that were greater than the national average. This may signal system-wide opportunities for surgeons and health system leaders to ensure uniform standards of care and reduce spending across the entire system. Importantly, for some of the highest-spending systems, nearly all of their hospitals are above the average system spending while other high-spending systems have some hospitals who's spending is less than average (figures 1-3). This observation may signal that for some systems, best practices from low-spending hospitals can be disseminated across the network, while for other systems best practices may need to be re-evaluated across the network.

Our approach has several limitations. First, our analysis does not distinguish systems based on size or geographic spread nor were we able to adjust for the degree of clinical or financial integration within these systems. Although some may interpret the system as a loose affiliation of hospitals, others may be more deliberate in coordinating providers and services. Second, as with other studies using administrative data, our findings are subject to residual confounding due to unmeasured factors such as patient severity, noncoded comorbidities, and sociodemographic factors. Third, the study was not longitudinal in nature in that we could not assess whether hospital spending changes after joining a system. Finally, it is important to note that not all institutional post- acute care is wasteful, and that reducing the utilization of these facilities past a certain point may be harmful for patients. However, there is reasonable evidence that post-acute care facilities do not improve long-term outcomes for cancer patients.[34]

Although hospital mergers proceed on the premise that they will achieve better care at lower cost, our data demonstrates that wide variation in spending across and within hospital systems among cancer surgery persists. Despite being affiliated in name, systems may still lack the financial alignment to strategically re-distribute care. The wide variations in episode spending observed in this study may indicate that the promise of better care at lower cost through care coordination has not been fully achieved. As both private and public payers aim to drive down surgical episode spending, systems will need to better control episode spending to remain competitive. This study suggests that strategies to curb variation in spending may have to be tailored to different operations within each system. For instance, some high-risk cancer operations may be best suited for centralization, while others may be better targets for standardization across the system. As hospital systems continue to evolve in response to broader financial pressures, surgeons and system leaders may be presented with unique opportunities for improving both the quality and cost of cancer care.

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Figure Legend

FIGURE 1. Variation in pancreatectomy spending within and across health systems. System and hospital average payments were price-standardized, winsorized to the 1st and 99th percentiles, and risk- and reliability- adjusted. The horizontal line represents the national average 30-d episode payment for pancreatectomy ($32,264). The small black dots represent average episode payments at the system level; systems are arrayed from lowest to highest average spending. The bubbles represent average episode payments at the hospital level; larger bubbles represent higher-volume hospitals. Bubbles within a vertical column represent hospitals within the same system. The solid circles represent the system hub (the hospital within each system with the highest volume).

FIGURE 2. Variation in lung resection spending within and across health systems. System and hospital average payments were price-standardized, winsorized to the 1st and 99th percentiles, and risk- and reliability- adjusted. The horizontal line represents the national average 30-d episode payment for lung resection ($20,973). The small black dots represent average episode payments at the system level; systems are arrayed from lowest to highest average spending. The bubbles represent average episode payments at the hospital level; larger bubbles represent higher-volume hospitals. Bubbles within a vertical column represent hospitals within the same system. The solid circles represent the system hub (the hospital within each system with the highest volume).

FIGURE 3. Variation in colectomy spending within and across health systems. System and hospital average payments were price-standardized, winsorized to the 1st and 99th percentiles, and risk- and reliability- adjusted. The horizontal line represents the national average 30-d episode payment for colectomy ($18,918). The small black dots represent average episode payments at the system level; systems are arrayed from lowest to highest average spending. The bubbles represent average episode payments at the hospital level; larger bubbles represent higher-volume hospitals. Bubbles within a vertical column represent hospitals within the same system. The solid circles represent the system hub (the hospital within each system with the highest volume).

Table 1 Health System characteristics by quintile of spending for each operation

		Quintile of Average System Spending					
	Overall	1	2	3	4	5	p-value
				Pancreatectomy			
Average total episode payment	$32,264	$31,481	$31,901	$32,114	$32,426	$33,427	
Number of cases	5,415	1,096	1,109	1,088	1,042	1,080	
Age, Mean (SD)	74.3 (5.9)	74.8 (6.0)	74.2 (5.7)	74.2 (6.0)	74.3 (6.0)	74.1 (5.7)	0.068
% Male	51%	48%	53%	51%	51%	52%	0.213
% White	89%	90%	91%	87%	89%	90%	0.006
% Black	6%	7%	5%	8%	4%	7%	0.005
No of Comorbidities (%)							
0	232 (4)	48 (4)	51 (5)	42 (4)	43 (4)	46 (4)	0.935
1	730 (13)	114 (10)	159 (14)	133 (12)	151 (15)	161 (15)	0.008
>2	4,609 (83)	934 (85)	899 (81)	913 (84)	848 (81)	873 (81)	0.020
Number of Systems	95	13	13	34	19	16	
Mean number of cases per system	140	163	156	71	136	108	<0.001
Mean number of hospitals per system	10	10	5	3	7	20	<0.001
Average annual volume at hub	97	173	119	67	63	55	<0.001
Average bed size at hub	894	945	1247	752	718	768	<0.001
Case concentration	76%	82%	76%	87%	65%	63%	<0.001
Number of Hospitals	322	61	42	61	77	81	
Mean number of cases per hospital	76	125	96	56	53	36	<0.001

% of patients treated at teaching hospital	65%	67%	67%	81%	66%	51%	<0.001
%of patients treated at urban hospital	97%	100%	97%	100%	95%	94%	<0.001
%of patients treated at for-profit hospital	9%	0%	2%	0%	10%	32%	<0.001
			Lung Resection				
Average total episode payment	$20,973	$20,700	$20,839	$20,929	$21,079	$21,325	
Number of cases	23,285	4,880	4,447	4,688	4,665	4,605	
Age, Mean (SD)	74.0 (5.6)	73.8 (5.5)	73.9 (5.6)	74.1 (5.6)	74.1 (5.6)	74.0 (5.5)	0.031
% Male	47%	48%	48%	45%	46%	48%	0.004
% White	91%	91%	90%	91%	91%	93%	<0.001
% Black	6%	6%	8%	5%	5%	4%	<0.001
No of Comorbidities (%)							
0	1,377 (6)	277 (6)	219 (5)	286 (6)	247 (7)	243 (5)	<0.001
1	4,005 (17)	803 (17)	697 (16)	854 (18)	918 (20)	717 (16)	<0.001
>2	17,971 (77)	3,800 (78)	3,531 (79)	5,548 (76)	3,400 (73)	3,645 (79)	<0.001
Number of systems	111	19	19	28	34	11	
Mean number of cases per system	489	511	412	352	228	946	
Mean number of hospitals per system	13	10	11	5	4	29	<0.001
Average annual volume at hub	166	150	133	192	197	92	<0.001
Average bed size at hub	792	894	614	690	938	771	<0.001
Case concentration	59%	47%	53%	65%	70%	42%	<0.001
Number of hospitals	563	99	108	97	110	149	
Mean number of cases per hospital	103	91	79	155	139	49	
% of patients treated at teaching hospital	40%	46%	28%	52%	52%	19%	<0.001
%of patients treated at urban hospital	97%	97%	95%	99%	96%	95%	<0.001
%of patients treated at for-profit hospital	13%	4%	1%	2%	4%	56%	<0.001
			Colon Resection				
Average total episode payment	$18,919	$18,417	$18,638	$18,890	$19,161	$19,513	
Number of cases	28,849	5,987	5,960	6,409	5,546	5,910	
Age, Mean (SD)	76.8 (7.3)	77.0 (7.3)	76.6 (7.3)	76.7 (7.3)	76.9 (7.4)	76.8 (7.3)	0.009
% Male	46%	46%	47%	46%	47%	47%	0.412
% White	89%	88%	89%	89%	87%	89%	<0.001
% Black	7%	8%	7%	7%	9%	7%	0.002
No of Comorbidities (%)							
0	2,071 (7)	396 (7)	446 (8)	431 (7)	347 (6)	448 (8)	0.018
1	5,067 (17)	1,038 (17)	1,020 (17)	1,047 (16)	951 (17)	1,005 (17)	0.624
>2	22,711 (76)	4,533 (76)	4,494 (75)	4,931 (77)	4,248 (77)	4,457 (75)	0.174
Number of systems	160	25	36	37	40	22	
Mean number of cases per system	548	432	385	462	231	1217	<0.001CI
Mean number of hospitals per system	17	12	10	12	8	42	<0.001
Average annual volume at hub	78	84	77	64	83	84	<0.001
Average bed size at hub	663	624	711	610	614	800	<0.001
Case concentration	47%	42%	46%	46%	53%	46%	<0.001
Number of hospitals	900	201	177	210	187	215	
Mean number of cases per hospital	48	48	53	44	55	43	<0.001
% of patients treated at teaching hospital	23%	21%	27%	23%	30%	16%	<0.001
%of patients treated at urban hospital	94%	94%	92%	95%	95%	94%	<0.001

%of patients treated at for-profit hospital	15%	3%	1%	5%	11%	57%	<0.001

NOTE: Quintiles of system spending were generated from risk- and reliability- adjusted estimates of system average payments and weighted at the episode level. Payments were price- standardized and winsorized to the 1st and 99th percentiles. Hospital and system characteristics were weighted at the episode level, to reflect differences in hospital and system volume. ''PAC:'' institutional post-acute care facility (eg, skilled nursing facility, rehabilitation facility, etc); Case concentration was calculated as the hub's case volume divided by the total system case volume for each system. Significance testing was also performed at the episode level using univariate statistics (ANOVA) as appropriate.

Table 2 Variation in spending across and within systems for each operation

	Across System Variation				**Within System Variation**			
		System Quintile		%Total Episode Payment		System Quintile		%Total Episode Payment
	Overall	1	5	Difference	Overall	1	5	Difference
Pancreatectomy								
Episode payments								
Average total episode	$32,264	$31,481	$33,427	100%	$2,034	$722	$5,682	100%
Average index hospitalization	$20,211	19,720	20,479	39%	$1,302	$462	$3,636	64%
Average physician	$5,760	5,620	5,990	19%	$244	$87	$682	12%
Average post-acute	$3,942	3,846	4,371	27%	$386	$137	$1,080	19%
Average readmission	$2,352	2,295	2,607	16%	$102	$36	$284	5%
Lung Resection								
Episode payments								
Average total episode	$20,973	$20,700	$21,326	100%	$1,789	$465	$4,305	100%
Average index hospitalization	$13,902	$13,721	$13,947	36%	$966	$251	$2,325	54%
Average physician	$3,592	$3,545	$3,658	18%	$286	$74	$689	16%
Average post-acute	$2,418	$2,387	$2,618	37%	$447	$116	$1,076	24%
Average readmission	$1,061	$1,047	$1,053	10%	$89	$23	$215	5%
Colectomy								
Episode payments								
Average total episode	$18,918	$18,559	$19,372	100%	$770	$211	$1,575	100%
Average index hospitalization	$12,450	$12,676	$12,798	15%	$408	$112	$835	53%
Average physician	$3,120	$2,987	$3,190	25%	$123	$34	$252	16%
Average post-acute	$2,359	$1,961	$2,343	47%	$185	$51	$378	24%
Average readmission	$990	$936	$1,042	13%	$54	$15	$110	7%

NOTE: Quintiles of system spending were generated from risk- and reliability- adjusted estimates of system average payments and weighted at the episode level. Within system variation generated by subtracting the the lowest spending hospital payments from the highest spending hospital payments for each system. Payments were price- standardized and winsorized to the 1st and 99th percentiles.

Table 3: Postoperative outcomes and discharge destination for highest and lost spending systems and hospitals for each operation

		Across System Variation			**Within System Variation**		
		System Quintile			System Hospital		
	Overall	1	5	p-value	Lowest-Spending	Highest Spending	p-value
Pancreatectomy							
Postoperative Outcomes							

Serious Complications	12.4	8.6	15.9	<0.001	11.1	12.7	0.277
Mortality, 30 days	4.8	5.5	5.5	0.992	5.0	4.0	0.353
Readmission	24.0	22.0	29.1	0.005	23.9	23.4	0.756
Discharge Destination							
Average across system:							
Home	39%	45%	34%		46%	32%	
Institutional PAC	22%	22%	28%		17%	26%	
Home Health	35%	28%	31%		35%	37%	
Other	5%	5%	7%		3%	5%	
Lung Resection							
Postoperative Outcomes							
Serious Complications	8.0	6.9	9.4	<0.001	6.8	8.1	0.003
Mortality, 30 days	2.3	2.2	2.8	0.082	2.0	1.8	0.493
Readmission	11.5	10.7	11.8	0.156	11.2	11.2	0.975
Discharge Destination							
Average across system:							
Home	57%	63%	54%		61%	60%	
Institutional PAC	12%	9%	16%		10%	12%	
Home Health	29%	25%	27%		28%	27%	
Other	2%	2%	3%		2%	2%	
Colectomy							
Postoperative Outcomes							
Serious Complications	4.9	3.9	5.6	<0.001	4.7	5.4	0.078
Mortality, 30 days	2.5	2.6	2.6	0.901	2.2	2.1	0.839
Readmission	12.3	10.7	13.6	0.000	11.5	13.2	0.025
Discharge Destination							
Average across system:							
Home	63%	66%	61%		65%	61%	
Institutional PAC	16%	13%	17%		15%	16%	
Home Health	18%	19%	18%		18%	20%	
Other	3%	3%	4%		2%	3%	

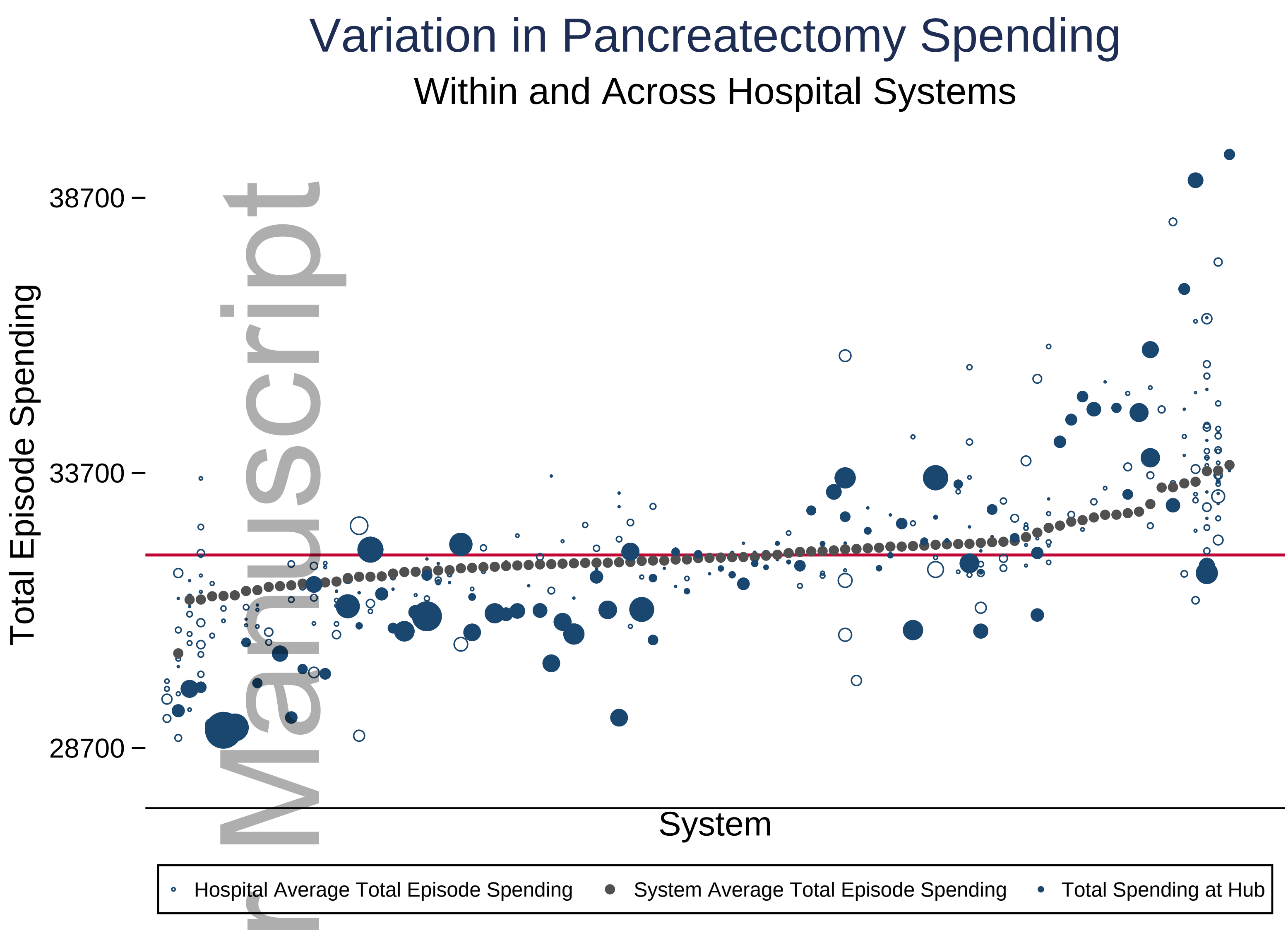
NOTE. For postoperative outcome risk-adjusted rates were derived using marginal means in logistic regression models in which outcome was treated as a categorical variable. All models were adjusted for patient age, sex, and 27 Elixhauser comorbidities, overall time trends, and hospital characteristics.

Table 4 Hub characteristics from the lowest- and highest-spending systems

		Across System Hubs		
		System Quintile		
	Overall	1	5	p-value
Pancreatectomy				
Average total episode	$31,639	$29,274	$34,623	<0.001
Hospital Volume	96	174	64	<0.001
Concentration	76%	85%	70%	<0.001
Teaching Hospital	82%	93%	81%	<0.001
Hospital beds	908	1027	591	<0.001

Discharge Destination				
Home	37%	48%	28%	<0.001
Institutional PAC	21%	20%	26%	
Home Health	36%	29%	43%	
Other	4%	4%	3%	
Lung Resection				
Average total episode	$20,593	$19,357	$22,190	<0.001
Hospital Volume	166	154	207	<0.001
Concentration	59%	60%	63%	<0.001
Teaching Hospital	63%	72%	67%	0.002
Hospital beds	797	808	1090	<0.001
Discharge Destination				
Home	60%	69%	41%	<0.001
Institutional PAC	10%	7%	16%	
Home Health	28%	22%	41%	
Other	2%	2%	2%	
Colectomy				
Average total episode	$18,898	$18,164	$19,662	<0.001
Hospital Volume	78	89	91	0.17
Concentration	47%	47%	44%	<0.001
Teaching Hospital	46%	41%	40%	0.78
Hospital beds	664	676	873	<0.001
Discharge Destination				
Home	63%	69%	56%	<0.001
Institutional PAC	15%	12%	19%	
Home Health	19%	16%	23%	
Other	2%	3%	3%	

NOTE: Quintiles of system spending were generated from risk- and reliability- adjusted estimates of hospital average payments at the hub for each system. Payments were price- standardized and winsorized to the 1st and 99th percentiles. ''PAC:'' institutional post-acute care facility (eg, skilled nursing facility, rehabilitation facility, etc); Case concentration was calculated as the hub's case volume divided by the total system case volume for each system. Significance testing was also performed at the episode level using univariate statistics as appropriate.



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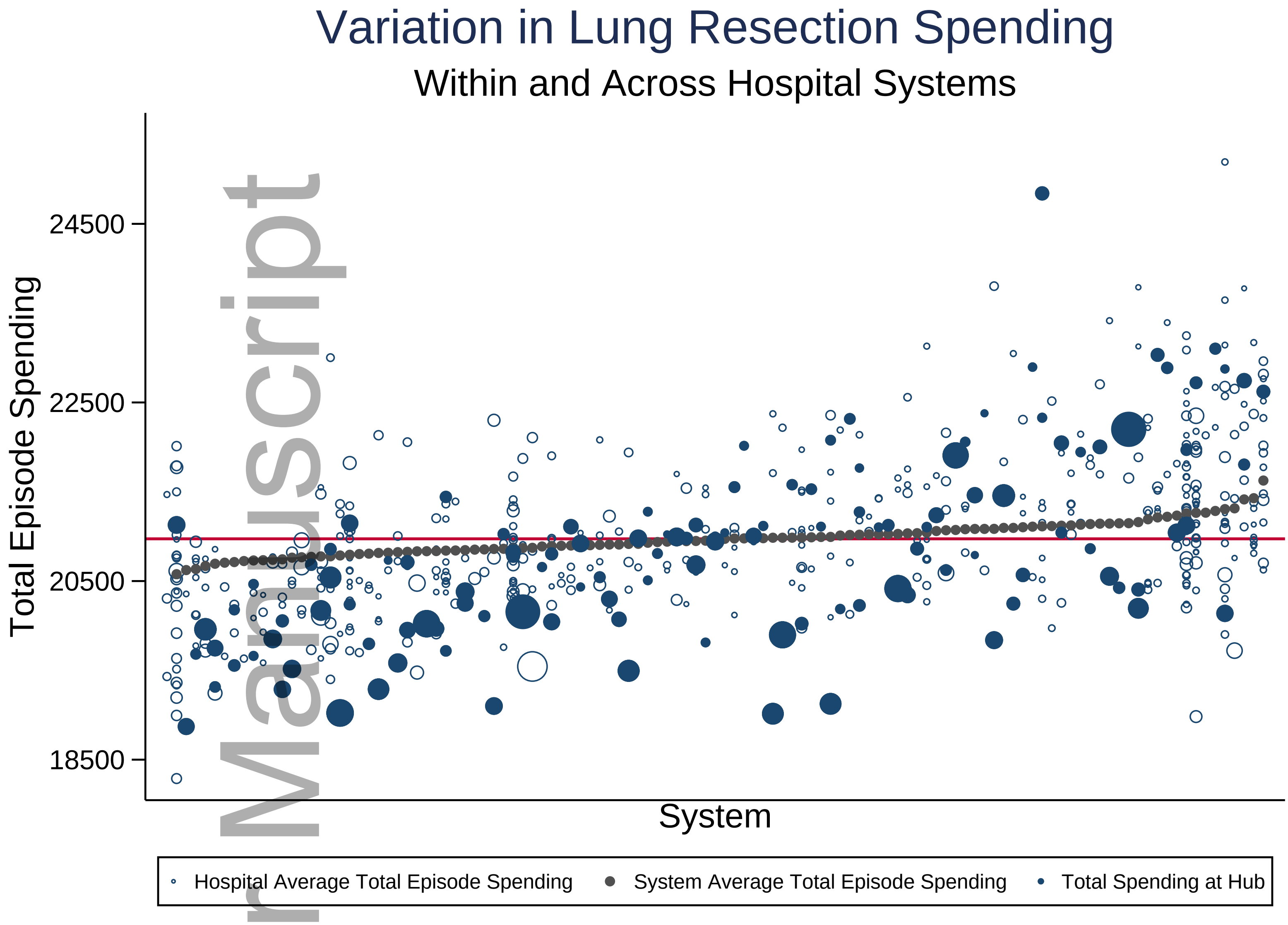

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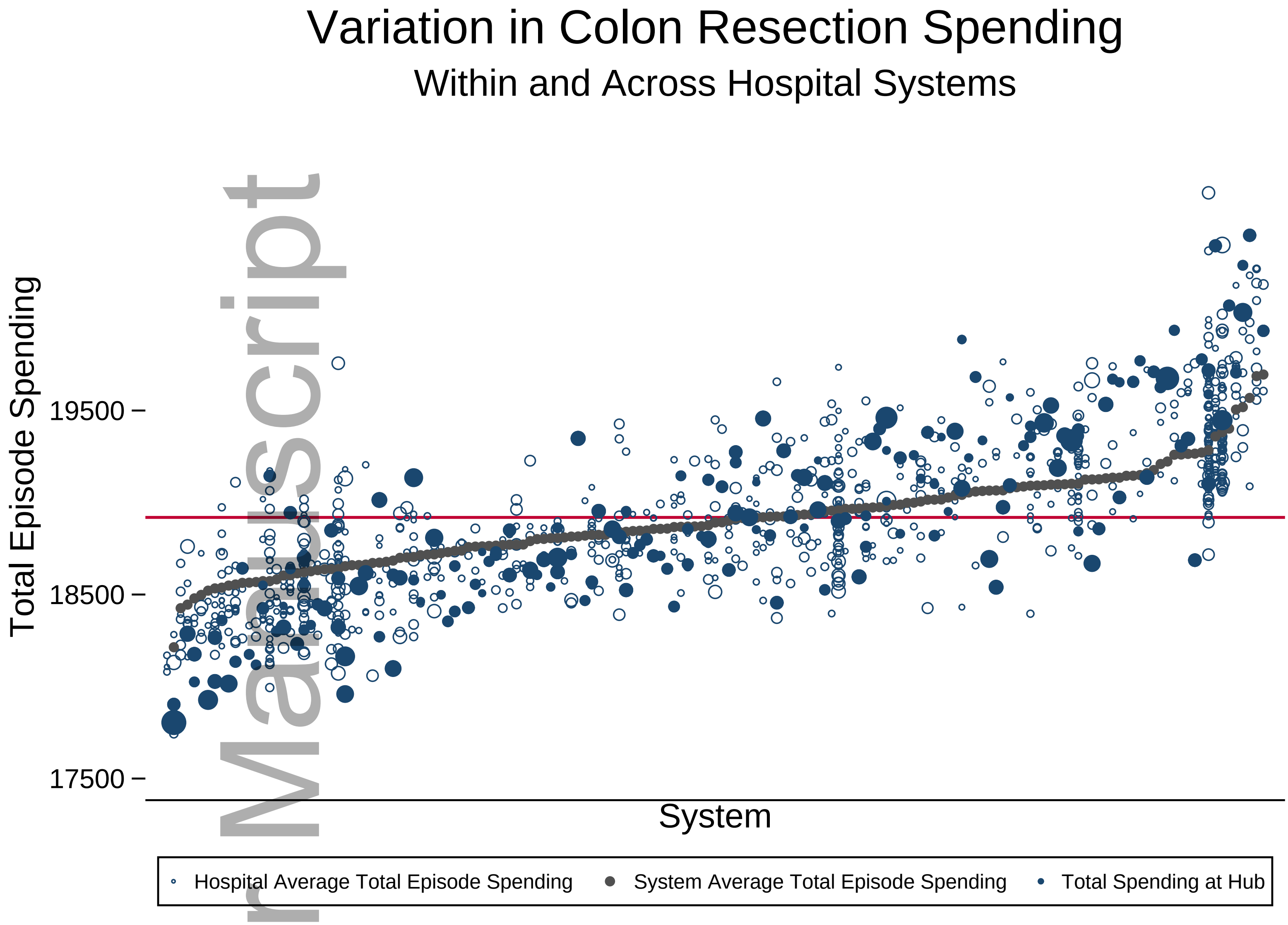

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