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Centralization of High-Risk Cancer Surgery Within Existing Hospital Systems

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abstract

PURPOSE Centralization is often proposed as a strategy to improve the quality of certain high-risk health care services. We evaluated the extent to which existing hospital systems centralize high-risk cancer surgery and whether centralization is associated with short-term clinical outcomes.

PATIENTS AND METHODS We merged data from the American Hospital Association's annual survey on hospital system affiliation with Medicare claims to identify patients undergoing surgery for pancreatic, esophageal, colon, lung, or rectal cancer between 2005 and 2014. We calculated the degree to which systems centralized each procedure by calculating the annual proportion of surgeries performed at the highest-volume hospital within each system. We then estimated the independent effect of centralization on the incidence of postoperative complications, death, and readmissions after accounting for patient, hospital, and system characteristics.

RESULTS The average degree of centralization varied from 25.2% (range, 6.6% to 100%) for colectomy to 71.2% (range, 8.3% to 100%) for pancreatectomy. Greater centralization was associated with lower rates of postoperative complications and death for lung resection, esophagectomy, and pancreatectomy. For example, there was a 1.1% (95% CI, 0.8% to 1.4%) absolute reduction in 30-day mortality after pancreatectomy for each 20% increase in the degree of centralization within systems. Independent of volume and hospital quality, postoperative mortality for pancreatectomy was two times higher in the least centralized systems than in the most centralized systems (8.9% *v* 3.7%, $P < .01$). Centralization was not associated with better outcomes for colectomy or proctectomy.

CONCLUSION Greater centralization of complex cancer surgery within existing hospital systems was associated with better outcomes. As hospitals affiliate in response to broader financial and organization pressures, these systems may also present unique opportunities to improve the quality of high-risk cancer care.

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INTRODUCTION

The practice of steering patients toward hospitals or providers with the most experience, commonly referred to as centralization, is often proposed as a strategy to improve outcomes and reduce treatment-related adverse events.[1] Centralization of high-risk cancer surgery has already received considerable attention because of the established relationship between surgical volume and mortality for operations like pancreatectomy and esophagectomy.[2,3] The Leapfrog Group, a national advocate for hospital transparency and patient safety, has supported minimum-volume standards at hospitals that perform high-risk cancer operations for decades. More recently, several academic health systems took a pledge to restrict these operations to hospitals and surgeons meeting predetermined volume thresholds.[4]

Europe, France and the Netherlands have successfully implemented centralization policies resulting in significant increases in short- and long-term survival for several GI malignancies.[5] However, it remains unclear whether this model can work in the United States. In the absence of specific policies or incentives, hospitals may be insufficiently motivated to shift patients and important sources of revenue to other centers. Recent trends in hospital mergers (which have doubled over the past decade) have created new opportunities for hospital systems to voluntarily organize care around the most experienced providers.[6] In doing so, systems could improve outcomes through better adherence to volume standards or by developing regional Centers of Excellence for oncologic services.[7,8] More than 60% of United States hospitals already participate in a system, but the impact of this national trend on cancer care is not well characterized.

In this study, we assessed the extent and impact of centralization for high-risk cancer surgery in the United States. Using data on Medicare beneficiaries

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undergoing five common, complex surgical procedures for cancer, we quantified variation in the degree of centralization among hospital systems. We then evaluated the association between centralization and short-term clinical outcomes and health care use.

PATIENTS AND METHODS

Data Source and Study Population

We used data encompassing 100% of Medicare Part A beneficiaries from Medicare Provider Analysis and Review files for the years 2005 to 2014. We collected data on patient age, demographic information, geographic location, and comorbidities. We included only patients from 65 to 99 years of age. We identified patients undergoing colectomy (1731 to 1736, 1739, 4571 to 4576, 4579, 4580 to 4583), proctectomy (4850 to 4852, 4862, 4863, 4869), esophagectomy (4240 to 4242, 4399), pancreatectomy (5251, 5253, 5260, 5270), and lung resection (323, 3230, 3239, 324, 3241, 3249, 325, 3250, 3259) for cancer using and International Classification of Disease, Ninth Revision, Clinical Modification codes. These procedures were chosen because they are common, carry significant risk of morbidity and mortality, and are often discussed within the context of potential centralization policies.[5]

We linked patient and hospital-level data from the Medicare Provider Analysis and Review files to the American Hospital Association (AHA) Annual Survey for the corresponding years (2005 to 2014) to obtain additional information on hospital characteristics, such as teaching status, urban versus rural location, bed size, and operating business model (eg, not for profit). The AHA database also includes variables (System ID) that permit the identification of discrete hospital systems and all their affiliated acute care hospitals. Although individual systems may have different referral patterns for complex care, there are no data on system behaviors. However, the AHA data are being widely used to study health systems and represent the most comprehensive source of data on hospital affiliations in the United States.

We defined centralization as the proportion of operations performed by the highest-volume center within each system in a given year. Hospital volume was determined as the raw number of each procedure performed annually in the Medicare population. Centralization numbers were calculated separately for each procedure because not all hospitals and systems performed each procedure.

Because Medicare covers only a proportion of patients undergoing these operations at United States hospitals, we used the National Inpatient Sample (NIS) to derive more complete estimates of hospital volume. For each procedure and year, we calculated proportions for each payer using the NIS. We then divided the Medicare-only volume from our primary analytic files by the proportion of patients covered by Medicare in NIS. The resulting number should therefore represent a more accurate estimate of a hospital's actual volume in a given year.

Outcomes

We used International Classification of Disease, Ninth and Tenth Revisions, Clinical Modification codes to identify 30-day postoperative complications such as pulmonary failure, pneumonia, myocardial infarction, deep venous thrombosis/pulmonary embolism, renal failure, surgical site infection, GI bleeding, and hemorrhage. These complications represent a subset of codes with the highest sensitivity and specificity.[9] We identified deaths as those occurring within 30 days of the index operation. We elected to use 30-day instead of 90-day mortality because it is measured more reliably in claims data and has been used most often as an outcome to motivate centralization discussions in the United States.[5,10] Readmissions were identified as any claim for a readmission to any hospital within 30 days after discharge.

Statistical Analysis

The purpose of this analysis was to evaluate the association between the extent of system centralization and postoperative complications, mortality, or readmissions. For each procedure and each outcome, we fit mixed-effects logistic regression models accounting for patient age, sex, and 27 Elixhauser comorbidities as fixed effects.[11] We further accounted for overall time trends toward better outcomes using the claim year as a categorical dummy variable. We accounted for additional hospital characteristics such as bed size, teaching status, business model, and nursing ratios as fixed effects, while also accounting for hospital-level random effects. We addressed potential confounding from existing hospital relationships (ie, system maturity) in two ways. First, we accounted for the average number of years of participation for all hospitals in a given system. Second, we accounted for the overall number of years for system participation for each hospital in any given year.

We modeled centralization as a continuous variable to derive estimates for the absolute risk difference associated with 20% increases in centralization from the linear regression models. We then used the logistic regression models to derive risk-adjusted outcome rates across systems stratified into quintiles on the basis of their degree of centralization.

We addressed the issue of system and hospital case volume in several ways, treating it as an effect modifier, rather than as a potential confounder. Using established, although arbitrary, annual volume standards from the Leapfrog Group (pancreatectomy, 20; esophagectomy, 20; lung resection, 40; proctectomy, 15), we identified hospitals achieving this benchmark in a given year (high-volume hospitals).[12,13] These standards are used to demonstrate volume relationships and not to make a particular comment

TABLE 1. Patient, Hospital, and System Characteristics Stratified by Procedure Type

Characteristic	Procedure				
	Pancreatectomy	Esophagectomy	Lung Resection	Colectomy	Proctectomy
Medicare patients					
No. of Medicare patients	37,280	23,125	247,215	464,749	89,976
Demographics					
Age, years, mean (SD)	74 (6)	73 (5)	74 (6)	78 (8)	75 (7)
Men	18,977 (50.9)	18,699 (80.9)	123,162 (49.8)	210,958 (45.4)	51,063 (56.8)
White	32,383 (87.3)	21,450 (93.3)	222,370 (90.3)	400,253 (86.4)	78,126 (87.3)
Black	2,688 (7.2)	793 (3.5)	15,392 (6.3)	42,407 (9.2)	6,164 (6.9)
Comorbidities					
Hypertension	20,380 (54.7)	11,691 (50.6)	150,415 (60.8)	269,353 (58.0)	52,439 (58.3)
Fluid and electrolyte disorders	11,641 (31.2)	6,917 (29.9)	39,271 (15.9)	113,470 (24.2)	18,768 (20.9)
Diabetes mellitus	9,490 (25.5)	4,043 (17.5)	43,216 (17.5)	90,654 (19.5)	17,389 (19.3)
Chronic pulmonary disease	4,844 (13.0)	4,728 (20.5)	126,189 (51.0)	77,827 (16.8)	13,955 (15.6)
Peripheral vascular disease	1,570 (4.2)	1,094 (4.7)	22,441 (9.1)	23,742 (5.1)	4,086 (4.5)
Obesity	1,944 (5.2)	1,398 (6.1)	14,062 (5.7)	29,274 (6.3)	5,824 (6.5)
Renal failure	1,676 (4.5)	1,061 (4.6)	14,429 (5.8)	35,137 (7.6)	5,009 (5.6)
Depression	1,827 (4.9)	908 (3.9)	15,012 (6.1)	21,591 (4.7)	3,827 (4.3)
Congestive heart failure	1,776 (4.8)	1,500 (6.5)	13,634 (5.5)	52,875 (11.4)	6,808 (7.6)
No. of Comorbidities					
0	2,082 (5.6)	2,063 (8.9)	16,063 (6.5)	29,155 (6.3)	9,012 (10.0)
1	7,128 (19.1)	5,399 (23.4)	50,368 (20.4)	84,686 (18.2)	21,111 (23.5)
≥ 2	28,070 (75.3)	15,663 (67.7)	180,784 (73.1)	350,908 (75.5)	59,853 (66.5)
Hospitals					
No. of hospitals	1,392	1,536	2,437	4,390	3,466
Medicare annual volume, mean (SD)	21 (22)	12 (13)	42 (50)	29 (22)	10 (10)
Medicare annual volume, median (IQR)	13 (2-24)	6 (2-13)	26 (8-44)	25 (2-51)	7 (3-12)
Total annual volume, mean (SD)*	40 (44)	25 (28)	75 (90)	60 (44)	21 (20)
Total annual volume, median (IQR)*	25 (1-50)	14 (1-28)	47 (15-79)	60 (26-76)	15 (6-24)
Size					
< 250 beds	344 (24.7)	415 (27.0)	1,155 (47.4)	3,077 (70.1)	1,937 (55.9)
250-499 beds	619 (44.5)	674 (43.9)	926 (38.0)	970 (22.1)	1,109 (32.0)
≥ 500 beds	429 (30.8)	447 (29.1)	356 (14.6)	342 (7.8)	419 (12.1)
Educational mission					
Teaching hospital	445 (32.0)	447 (29.1)	356 (14.6)	351 (8.0)	412 (11.9)
Nonteaching hospital	947 (68.0)	1,089 (70.9)	2,081 (85.4)	4,039 (92.0)	3,054 (88.1)
Business model					
Investor owned	155 (11.1)	178 (11.6)	417 (17.1)	764 (17.4)	558 (16.1)
Not for profit	1,077 (77.4)	1,197 (77.9)	1,750 (71.8)	2,884 (65.7)	2,478 (71.5)
Other	160 (11.5)	161 (10.5)	271 (11.1)	742 (16.9)	430 (12.4)
Geographic location					
Urban	1,335 (95.9)	1,452 (94.5)	2,210 (90.7)	4,052 (92.3)	3,147 (90.8)
Rural	57 (4.1)	84 (5.5)	227 (9.3)	338 (7.7)	319 (9.2)

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TABLE 1. Patient, Hospital, and System Characteristics Stratified by Procedure Type (continued)

Characteristic	Procedure: Pancreatectomy	Esophagectomy	Lung Resection	Colectomy	Proctectomy
Systems					
No. of systems	287	301	334	358	351
System size, median (IQR)	8 (2-14)	9 (2-19)	9 (2-23)	11 (2-36)	11 (2-26)
Degree of centralization, %					
Mean	71.2	51.3	39.0	25.2	33.4
Range	8.3-100	5.6-100	4.3-100	6.6-100	2.5-100
Medicare annual volume, mean (SD)	42 (36)	25 (22)	236 (284)	483 (617)	92 (117)
Medicare annual volume, median (IQR)	30 (5-55)	16 (2-30)	111 (10-212)	183 (5-517)	38 (3-84)
Total annual volume, mean (SD)*	80 (71)	54 (49)	587 (430)	815 (663)	244 (231)
Total annual volume, median (IQR)*	58 (7-108)	61 (6-120)	410 (202-634)	768 (356-1,082)	153 (38-285)

NOTE. Data presented as No. (%) unless otherwise indicated.

Abbreviations: IQR, interquartile range; SD, standard deviation.

*Total annual volume figures estimated using payer mix for each procedure from National Inpatient Sample data for each corresponding study year. Average annual volumes may not reflect total case volume because certain lower-volume hospitals may not perform particular operations every year.

on their usefulness to inform centralization. Volume standards for colectomy are not reported, but we used a threshold of 15 cases because of its technical similarity to proctectomy, and prior evidence suggests that this would be a clinically reasonable benchmark.[14] We also defined low- and high-volume systems as those below or above the median system volume, respectively. We repeated the primary analyses across four discrete groups of systems (low volume, high volume, systems without a high-volume hospital, and systems with a high-volume hospital) to provide estimates that account for differential access to resources across the systems.

All statistical analyses were performed using STATA statistical software version 14 (College Station, Texas). We used a two-sided approach at the 5% significance level for all hypothesis testing. This study was deemed exempt by the institutional review board at the University of Michigan.

RESULTS

Patient, Hospital, and System Characteristics

Characteristics of patients, hospitals, and systems are included in Table 1. Patient characteristics were similar overall among procedure groups. The proportion of patients with two or more comorbidities ranged from 66.5% for proctectomy to 75.5% for colectomy. The largest number of hospitals performed colectomy (4,390), whereas fewer performed esophagectomy (1,536) and pancreatectomy (1,392). Median annual hospital volume after applying cohort exclusions ranged from six (interquartile range, two to 13) for esophagectomy to 26 (interquartile range, 8-44) for lung resection. The largest number of systems (358) contained at least one hospital performing colectomy. In contrast, the fewest number of systems (287) contained at least one hospital performing pancreatectomy.

The average degree of centralization varied from 25.2% (range, 6.6% to 100%) for colectomy to 71.2% (range, 8.3% to 100%) for pancreatectomy. The proportion of systems that met annual Leapfrog volume thresholds across all their affiliates combined varied by procedure: pancreatectomy (25.8%), esophagectomy (15.5%), proctectomy (47.1%), lung resection (49.9%), and colectomy (90.4%). A significant proportion of systems did not contain even one hospital that met the annual volume threshold. This ranged from 85% for esophagectomy to 74.2% for pancreatectomy, 52.9% for proctectomy, 50.1% for lung resection, and 9.6% for colectomy.

Association Between Centralization and Postoperative Outcomes

Greater centralization was associated with lower rates of postoperative complications and death for lung resection, esophagectomy, and pancreatectomy (Table 2). For example, there was a 1.1% (95% CI, 1.4% to 0.8%) absolute reduction in 30-day mortality after pancreatectomy for each 20% increase in the degree of centralization within systems. Centralization was associated with changes in readmission rates after esophagectomy only. For esophagectomy, a 20% increase in centralization was associated with a 1.5% (95% CI, 0.9% to 2.0%) absolute increase in readmissions.

Risk-adjusted outcome rates across the continuum of system centralization are illustrated in Fig 1. For example, postoperative mortality for pancreatectomy was two times higher in the least centralized systems than in the most centralized systems (8.9% *v* 3.7%, $P < .01$). Similarly, postoperative complications were 22.5% lower in the most centralized systems than in the least centralized systems (27.6% *v* 35.6%, $P < .01$) after pancreatectomy. Readmission rates after esophagectomy were 30.1% higher in the most centralized systems than in the least centralized

TABLE 2. Average Independent Effect of Centralization on Short-Term Postoperative Outcome Rates Stratified by Procedure Type

Procedure	Absolute Risk Reduction Per 20% Increase in Centralization (95% CI)	Risk-Adjusted Rates (95% CI)	
		Least Centralized Systems	Most Centralized Systems
Pancreatectomy			
Any complication	−1.6 (−2.3 to −0.9)	35.6 (32.5 to 36.6)	27.6 (25.3 to 30.0)
Death, 30 day	−1.1 (−1.4 to −0.8)	8.9 (7.6 to 10.1)	3.7 (2.9 to 4.4)
Readmission, 30 day	0.4 (−0.1 to 0.9)	21.3 (18.9 to 21.7)	22.9 (21.5 to 24.2)
Esophagectomy			
Any complication	−1.5 (−2.2 to −.0.8)	41.4 (39.0 to 43.7)	34.7 (32.8 to 36.7)
Death, 30 day	−1.2 (−1.5 to −0.8)	10.3 (8.8 to 11.7)	4.8 (3.9 to 5.8)
Readmission, 30 day	1.5 (0.9 to 2.0)	19.3 (18.1 to 21.1)	25.2 (23.4 to 27.0)
Lung resection			
Any complication	−0.7 (−1.1 to −0.4)	18.8 (17.5 to 20.1)	16.3 (15.3 to 17.2)
Death, 30 day	−0.3 (−0.5 to −0.2)	5.4 (4.8 to 5.9)	3.7 (3.3 to 4.1)
Readmission, 30 day	0.2 (0.0 to 0.4)	11.6 (11.0 to 12.3)	12.7 (12.1 to 13.4)
Colectomy			
Any complication	0.2 (0.0 to 0.5)	24.7 (24.0 to 25.5)	24.2 (23.6 to 24.8)
Death, 30 day	−0.1 (−0.2 to 0.1)	6.1 (5.7 to 6.5)	6.1 (5.8 to 6.4)
Readmission, 30 day	0.1 (−0.1 to −0.2)	12.6 (12.0 to 13.1)	13.0 (12.6 to 13.4)
Proctectomy			
Any complication	0.0 (−0.4 to 0.3)	20.8 (19.7 to 21.9)	20.1 (19.2 to 21.0)
Death, 30 day	−0.2 (−0.3 to 0.0)	3.8 (3.2 to 4.4)	3.0 (2.7 to 3.4)
Readmission, 30 day	0.2 (−0.1 to 0.6)	18.0 (16.8 to 19.2)	18.3 (17.4 to 19.2)

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

systems (25.2 *v* 19.3%, $P < .01$). Trends in readmissions to another hospital within the system or overall were similar to our primary analysis. Trends in failure to rescue (death after a complication) were similar to those observed with 30-day mortality.

Effect of System Versus Hospital Volume

Although hospital systems varied in their overall procedural volume, the association between centralization and short-term outcomes was consistent across the observed range of system volume (Table 3). For example, the most centralized low-volume systems performing esophagectomy (6.3% [95% CI, 5.1% to 7.4%]) had significantly lower mortality than the least centralized systems (12.3% [95% CI, 9.5% to 15.1%], $P < .01$). Even when restricted to systems without a center meeting the minimum volume standards for safe surgery, mortality rates for the most centralized systems (6.1% [95% CI, 3.9% to 8.4%]) were lower than those at the least centralized systems (9.9% [95% CI, 8.6% to 11.2%], $P < .01$).

DISCUSSION

Although the volume–outcome benefit for complex cancer surgery is widely recognized, the absence of specific policies and economic incentives has prevented centralization from being effectively studied or used as a strategy to improve the quality of high-risk cancer surgery in the United States. In this study, we capitalized on the longitudinal trend toward hospital consolidation and the natural opportunities that it presents to centralize care within an established system of affiliated hospitals. We found that the degree of centralization varied widely across hospital systems for each procedure, with pancreatectomy and esophagectomy being the most centralized on average. For three procedures (pancreatectomy, esophagectomy, and lung resection) greater centralization was associated with better outcomes. Centralization was not associated with better or worse outcomes after colectomy or proctectomy. We observed that systems varied substantially in their overall volume, such that their opportunity to leverage their collective experience would similarly vary. However, centralization was associated with significant benefits for both low- and high-volume systems, suggesting that this strategy would have broadly applicable benefits.

Several European countries have successfully implemented centralization policies that have proven effective in reducing short-term morbidity from high-risk surgeries in addition to improving long-term oncologic outcomes for

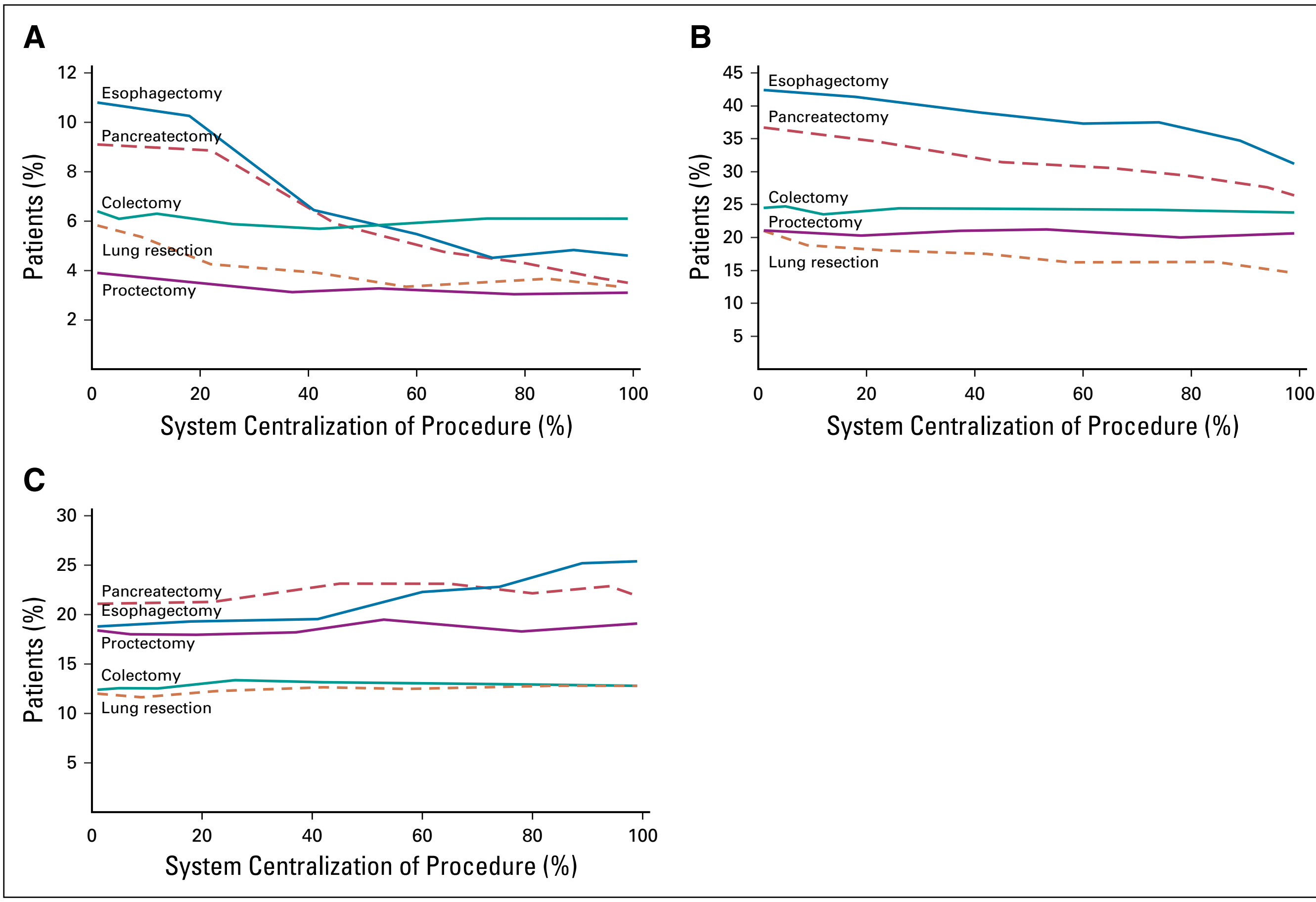

FIG 1. Risk-adjusted rates of postoperative (A) death, (B) complications, or (C) readmissions for each procedure across the continuum of systems' centralization of each procedure. Estimates reflect the trend in each outcome from models in which centralization was modeled continuously.

gastric, pancreatic, and rectal cancers.[15,16] For example, 90-day mortality after gastrectomy decreased from 11% to 7%, whereas 2-year survival increased from 55% 59% after the Netherlands centralized the procedure to select centers in 2012.[17] In contrast, Canada centralized lung cancer surgery in 2007, but the policy failed to demonstrate desired improvements in postoperative mortality.[18] The extent to which the success of centralization policies is related to the overall population size of the country or the unique design of its health care systems is unclear.

The United States health care system differs from those in Europe and Canada in several important ways relevant to potential policies to centralize care. First, the patient, provider, and hospital populations are much larger. Second, the federal government has little to no control of hospital credentialing. Physicians and hospitals have considerable autonomy in determining where, and by whom, procedures will be performed.[19] Third, the payer mix is more diverse, with extensive private markets and no universal public option provided by the government. This study recognizes that ongoing horizontal integration may be a natural framework for studying whether centralization is a tool to improve cancer care in United States markets.[6,20,21] Successful mergers should leverage collective assets, reorganize delivery systems, and optimize care around the most experienced providers when necessary.[22] That said, the United States is much less centralized at baseline, and approaches to centralize care will likely require greater input from physicians, clinical societies, and policy makers to be most effective. Furthermore, implementing centralization protocols to improve patient safety and overall care should focus on ways to reduce harm. There is a wide body of literature suggesting that failure to rescue is an important driver of postoperative mortality. Centralization of care may help direct patients to the hospitals with not only the most experience treating complex cancers, but also the most experience in managing the complications that are to be expected from major oncologic resections.[23,24]

The findings in this study should be considered within the context of several important limitations. Each of the cancer-related procedures is more common in aged populations, and our results may not be generalizable to all patients. This study may also be limited by the measurement of only a subset of complications and 30-day mortality. In doing so, we may exclude other clinically meaningful outcomes.

TABLE 3. Sensitivity Analyses to Evaluate the Effect of Hospital and System Volume on Short-Term Postoperative Outcome Rates for Each Procedure

	Risk-Adjusted Rates (95% CI)					
	Complications		Death, 30 Day		Readmission, 30 Day	
Procedure	Least Centralized Systems	Most Centralized Systems	Least Centralized Systems	Most Centralized Systems	Least Centralized Systems	Most Centralized Systems
Pancreatectomy						
Low-volume systems	37.5 (33.7 to 41.3)	27.9 (25.4 to 30.3)	11.3 (8.7 to 13.8)	3.8 (2.7 to 4.8)	18.7 (15.4 to 21.9)	23.1 (20.6 to 25.5)
High-volume systems	31.9 (20.6 to 33.3)	27.1 (25.5 to 28.7)	7.1 (6.3 to 7.9)	3.5 (2.8 to 4.2)	20.9 (19.6 to 22.2)	23.0 (21.4 to 24.6)
Systems without high-volume hospital	35.9 (33.5 to 38.3)	29.1 (22.5 to 35.7)	9.4 (7.8 to 10.9)	4.7 (2.5 to 6.9)	19.6 (17.5 to 21.7)	29.6 (24.4 to 34.7)
Systems with high-volume hospital(s)	32.1 (30.6 to 33.7)	26.9 (25.6 to 28.3)	7.1 (6.2 to 8.0)	3.5 (2.9 to 4.1)	21.2 (19.7 to 22.7)	22.7 (21.3 to 24.0)
Esophagectomy						
Low-volume systems	43.0 (38.9 to 47.1)	35.7 (33.4 to 37.8)	12.3 (9.5 to 15.1)	6.3 (5.1 to 7.4)	21.6 (18.0 to 25.2)	24.0 (22.0 to 26.1)
High-volume systems	39.5 (37.6 to 41.3)	35.7 (31.7 to 39.6)	7.5 (6.5 to 8.5)	3.4 (1.8 to 5.0)	19.7 (18.1 to 21.2)	28.2 (24.3 to 32.2)
Systems without high-volume hospital	41.8 (39.7 to 43.9)	37.1 (34.8 to 39.5)	9.9 (8.6 to 11.2)	6.1 (3.9 to 8.4)	19.6 (17.8 to 21.4)	22.1 (18.1 to 26.2)
Systems with high-volume hospital(s)	38.1 (36.3 to 39.8)	34.7 (33.6 to 35.8)	6.4 (4.9 to 7.8)	5.1 (4.1 to 6.1)	21.0 (18.6 to 23.4)	25.3 (23.3 to 27.4)
Lung resection						
Low-volume systems	23.3 (19.3 to 28.3)	16.6 (16.2 to 17.0)	5.2 (2.4 to 7.9)	3.5 (3.3 to 3.7)	15.2 (10.6 to 20.4)	12.5 (12.1 to 12.9)
High-volume systems	18.8 (18.4 to 19.1)	13.6 (12.2 to 15.1)	4.3 (4.2 to 4.6)	1.0 (0.6 to 1.5)	12.1 (11.8 to 12.5)	12.2 (10.7 to 13.7)
Systems without high-volume hospital	20.7 (19.7 to 21.7)	19.7 (18.5 to 20.8)	4.5 (4.0 to 5.1)	4.2 (3.6 to 4.8)	8.8 (6.7 to 10.4)	12.1 (11.1 to 13.0)
Systems with high-volume hospital(s)	18.7 (18.3 to 19.1)	15.9 (15.5 to 16.3)	4.4 (4.2 to 4.6)	3.2 (3.0 to 3.5)	12.1 (11.8 to 12.5)	12.6 (12.2 to 13.0)
Colectomy						
Low-volume systems	22.2 (20.4 to 24.0)	23.5 (23.2 to 23.8)	7.5 (6.3 to 8.7)	5.9 (5.7 to 6.1)	13.2 (11.7 to 14.8)	12.9 (12.7 to 13.2)
High-volume systems	24.7 (23.9 to 24.6)	25.5 (24.6 to 26.4)	6.5 (6.3 to 6.7)	6.2 (5.6 to 6.7)	12.6 (12.4 to 12.8)	13.1 (12.2 to 13.9)
Systems without high-volume hospital	22.6 (17.8 to 27.5)	24.3 (21.3 to 27.4)	7.4 (3.8 to 10.9)	6.1 (4.4 to 7.8)	11.7 (7.9 to 15.2)	15.7 (12.9 to 18.5)
Systems with high-volume hospital(s)	24.1 (23.7 to 24.4)	23.6 (23.2 to 23.8)	6.5 (6.3 to 6.7)	5.9 (5.8 to 6.1)	12.6 (12.4 to 12.8)	12.9 (12.7 to 13.2)
Proctectomy						
Low-volume systems	23.6 (18.6 to 28.6)	19.7 (18.9 to 20.3)	7.4 (4.4 to 10.4)	3.1 (2.8 to 3.5)	20.0 (14.9 to 25.1)	18.3 (17.6 to 19.0)
High-volume systems	21.8 (21.1 to 22.4)	19.1 (13.4 to 25.9)	3.5 (3.2 to 3.8)	2.3 (1.5 to 3.1)	17.9 (17.2 to 18.5)	19.0 (10.8 to 27.3)
Systems without high-volume hospital	23.9 (18.9 to 28.9)	20.4 (18.8 to 21.9)	7.9 (4.8 to 11.1)	3.7 (3.0 to 4.5)	19.4 (14.4 to 24.5)	18.2 (16.7 to 19.9)
Systems with high-volume hospital(s)	21.4 (20.8 to 22.1)	19.7 (18.9 to 20.4)	3.5 (3.2 to 3.8)	3.0 (2.6 to 3.3)	17.8 (17.1 to 18.4)	18.4 (17.6 to 19.2)

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

However, we used complications that have been shown previously to be measured reliably in claims data, to limit any potential bias from measurement error alone. A key limitation of this study centers on the definition of a hospital system. Although some may interpret the system as a loose affiliation of hospitals, others may be more deliberate in coordinating providers and services. Nonetheless, there are no current standards by which hospital system behavior is categorized. However, in all analyses, we did account for several organizational characteristics that may influence outcomes, such as the hospitals' time-in-system. We were unable to determine whether centralization occurred randomly or with intention. However, this distinction would not change the underlying premise of our analysis, which explored how centralization overall influences surgical outcomes. Finally, there is an important connection between centralization and hospital volume. Certain procedures may be coded incorrectly in low-volume hospitals. However, we limited this issue by requiring agreement between the procedure and the operative diagnosis. The Leapfrog thresholds are used to demonstrate effect, not to support their use to inform practice changes. Furthermore, simply adjusting for volume as a confounder would not account for the possibility that centralization influences outcomes for other reasons (eg, the coordination of other cancer care specialists). Thus, we presented several secondary analyses that explore how surgical case volumes could influence our primary findings.

Any discussion about centralization should consider the structure around which care is to be centralized (ie, geographic, organizational, or through a set of established criteria [eg, volume standards]). Geographic or ad hoc centralization of cancer surgery is well documented. In the decade between the 1990s and the early 2000s, the proportion of esophageal, pancreatic, and colon cancer surgeries performed by the highest-volume hospitals doubled.[10] Criteria-based centralization is becoming increasingly common. For example, a recent initiative by the Commission on Cancer and the American College of Surgeons established the National Accreditation Program for Rectal Cancer.[25] This initiative uses evidence-based standards to accredit centers with the clinical, research, and outcomes reporting infrastructure to care for patients with rectal cancer. Building on decades of work by the Leapfrog Group, volume criteria have also received considerable attention as certain centers have taken the volume pledge, which restricts complex surgeries to the most experienced providers.[4]

For each example, however, clinicians and policymakers have raised legitimate concerns that these models for centralization may increase disparities, exacerbate access issues, and even impede the training of future physicians.[26] Centralizing cancer care around existing hospital systems may be a strategic alternative that addresses many of these concerns. Hospital systems are oriented regionally and have a clear interest in addressing the clinical needs, and capitalizing on the market demands, of their geographic location.[22] Centralization within systems also aligns credentialing entities with the broader strategic planning initiatives for the entire system to improve patient safety. Finally, the system model of centralization preserves existing business relationships and may mitigate some of the concerns that come from imposing external centralization criteria, such as loss of revenue.

In this national, population-based study of Medicare beneficiaries undergoing high-risk cancer surgery, short-term outcomes were better when patients had surgery within the most centralized systems. As hospitals affiliate in response to broader financial and organizational pressures, their systems may present unique opportunities for improving the quality of high-risk cancer care in the United States.

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AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST AND ADAT AVAILABILITY STATEMENT

Centralization of High-Risk Cancer Surgery Within Existing Hospital Systems

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