ORIGINAL REPORT

Centralization of Cancer Surgery: Implications for Patient Access to Optimal Care

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ABSTRACT

Purpose
The volume-outcomes relationship has led many to advocate centralization of cancer procedures at high volume hospitals (HVH). We hypothesized that in response cancer surgery has become increasingly centralized and that this centralization has resulted in increased travel burden for patients.

Patients and Methods
Using 1996 to 2006 discharge data from NY, NJ, PA, all patients ≥ 18 years old treated with extirpative surgery for colorectal, esophageal, or pancreatic cancer were examined. Patients and hospitals were geocoded. Annual hospital procedure volume for each tumor site was examined, and multiple quantile and logistic regressions were used to compare changes in centralization and distance traveled.

Results
Five thousand two hundred seventy-three esophageal, 13,472 pancreatic, 202,879 colon, and 51,262 rectal procedures were included. A shift to HVH occurred to varying degrees for all tumor types. The odds of surgery at a low volume hospital decreased for esophagus, pancreas and colon: per year odds ratios (ORs) were 0.87 (95% CI, 0.85 to 0.90), 0.85 (95% CI, 0.84 to 0.87), and 0.97 (95% CI, 0.97 to 0.98). Median travel distance increased for all sites: esophagus 72%, pancreas 40%, colon 17%, and rectum 28% ($P < .0001$). Travel distance was proportional to procedure volume ($P < .0001$). The majority of the increase in distance was attributable to centralization.

Conclusion
There has been extensive centralization of complex cancer surgery over the past decade. While this process should result in population-level improvements in cancer outcomes, centralization is increasing patient travel. For some subsets of the population, increasing travel requirements may pose a significant barrier to access to quality cancer care.

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INTRODUCTION

Over the past 30 years, a wealth of publications documenting relationships between hospital procedure volume and clinical outcomes has emerged.[1,2] Most recently, there is increasing focus on the volume-outcome relationships for cancer care.[3-6] The evidence documenting an inverse relationship between mortality and hospital procedure volume for pancreatic and esophageal surgery has caused many to advocate centralization of these procedures at high volume hospitals (HVH).[3,7-12] Others worry centralization may create access problems for a substantial portion of patients and worsen existing disparities between those who are treated at HVH versus low volume hospitals (LVH).[2,13-23] Despite general accep-tance of the volume-outcome relationships for complex cancer operations, little is known about how patterns of care in the United States have changed in response to recently published studies.[24-28]

In this observational study, we do not attempt to reconfirm the volume-outcome relationships for cancer surgery, but rather we examine changes in the distribution of cases among hospitals with differing procedure volumes and document how this has evolved over time. We address the impact changes have had on travel distance for patients with cancer and investigate whether existing disparities have been exacerbated by centralization of cancer surgery. We hypothesize that centralization has substantially increased the travel distance for patients and has exacerbated existing disparities relating to treatment at high versus low volume centers.

PATIENTS AND METHODS

A secondary data analysis was performed using discharge data from NJ, NY, and PA. Available data included demographic information (including race as documented in the medical record), clinical diagnoses, procedure codes, length of stay, disposition at discharge, and hospital charges.

All patients ≥ 18 years of age undergoing procedures in the service area (NJ, NY, PA) from 1996 to 2006 were included. From 1996 to 1999, only NY and PA data were available. Starting in 2000, procedures from all three states were included. The most common primary gastrointestinal malignancies were chosen for study. International Classification of Diseases 9th revision procedure codes captured all pancreatectomies, esophagectomies, colectomies, and proctectomies, as well as local surgical excision of masses at these sites (ie, transanal excision of rectal mass). Endoscopic resections were excluded. The study group was further limited to cases with an International Classification of Diseases 9th revision diagnosis code for neoplasm.

Cases were geocoded to zip code centroid and linked to publicly available area-based sociodemographic data. Hospitals were geocoded to actual street
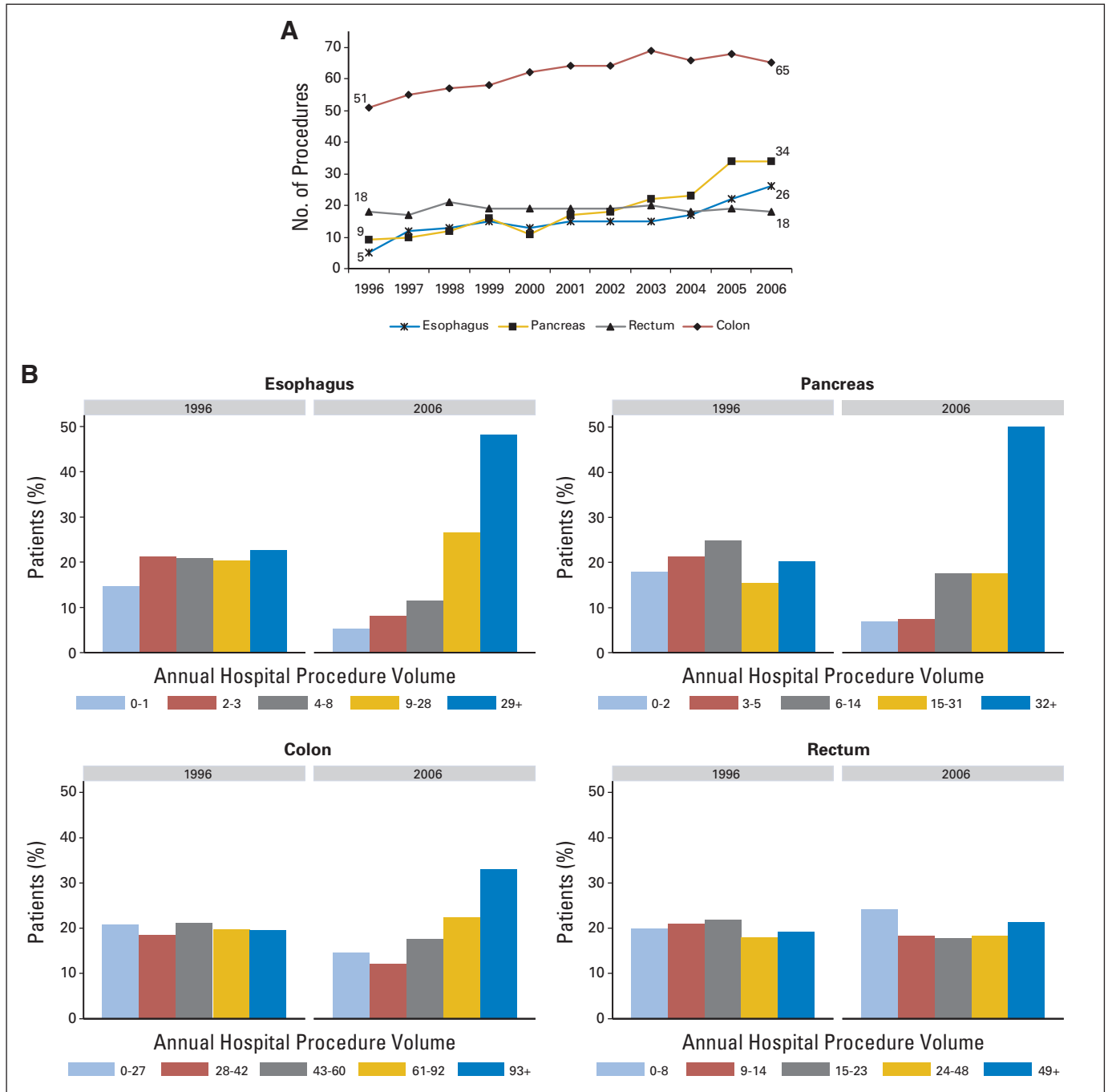
Fig 1. Procedure volume over time. (A) Median procedure volume. Values should be interpreted as volume for the 50th percentile of all cases. For example, in 1996, half of all resections for esophageal cancer were performed at a hospital that did ≤ 5 such procedures that year. In contrast, in 2006, half of all esophageal cancer resections were performed at a hospital that did ≥ 26 resections. (B) Distribution of procedures among volume categories based on 1996 quintile cut points.

address. Straight-line distance was calculated between cases and the hospitals at which the procedures were performed as well as between cases and the nearest HVH or very high volume hospital (VHVH).[29]

Hospital procedure volume of extirpative procedures for each organ site was calculated for each year individually, allowing for the possibility that volume at a given hospital could change over time. Five roughly equal-sized groups of patients were created for each organ site in 1996 based on procedure volume of the treating hospital. These quintiles were designated very low, low, medium, high, and very high volume. The 1996 cut points were then applied to each subsequent year in order to determine changes in the distribution of patients among volume categories. Similarly, 1996 tercile cut points were created for each organ site. Multiple logistic regressions provided estimates of the odds of receiving care at a hospital in the lowest tercile over time, examining year as a continuous variable and controlling for the overall number of cases performed in the study area annually. Using the same data set, annual market-wide in-hospital mortality was calculated for each organ site.

We used multiple quantile regressions to investigate median time trends in distance traveled. We added an indicator variable of treatment in the highest volume tercile to investigate if coefficients of the year main effects and interaction terms changed after controlling for high volume tercile. We used similar multiple quantile regressions to investigate if time trends in distance varied by rurality status and to investigate the relationship between median distance and the number of available HVH.

Using multiple logistic regressions, we investigated the association between sociodemographic factors and the odds of having a surgery at a LVH in 1996 to 1997 and 2005 to 2006. Interaction models were used to investigate if the strength of associations changed between the two time points.

All hypothesis tests were two sided, and the criterion for statistical significance was a $P < .05$. Data were deidentified, and the study was approved by the institutional review board of Fox Chase Cancer Center.

RESULTS

Two hundred seventy-two thousand eight hundred eighty-six procedures met criteria for inclusion (5,273 esophagus, 13,472 pancreas, 202,879 colon, 51,262 rectum). Inward border crossers (patients residing outside the study area who had surgery within the study area) comprised 1.8% of the study population: esophagus 7.2% (382 of 5,273), pancreas 4.9% (666 of 13,472), colon 1.4% (2,857 of 202,879), rectum 2.0% (1,014 of 51,262).
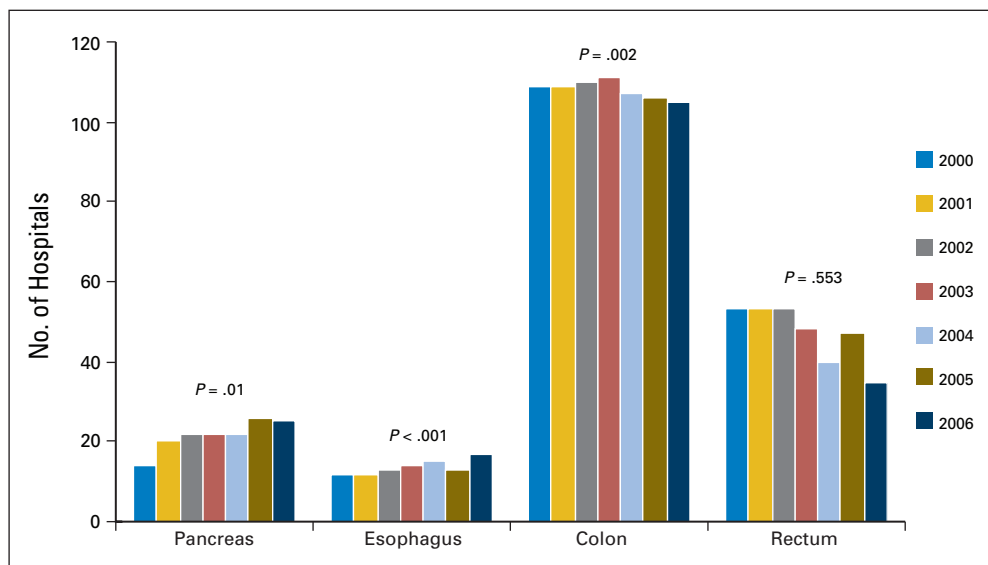
Centralization

A shift from LVH to HVH occurred to varying degrees for esophageal, pancreatic, and colon cancer procedures (Figs 1A, 1B). For esophageal and pancreatic procedures, this process is ongoing without evidence of abating. In contrast to the other organ sites, the distribution of rectal cancer procedures between volume groups did not change substantially over time.

To accommodate the centralization, there was an increase in the number of HVH and VHVH (Fig 2) as well as an increase in the number of procedures performed at existing HVH and VHVH. Average procedure volume for the top five HVH for pancreatic cancer surgery increased from 62.8 to 125 cases/year from 2000 to 2006. Similarly, for esophageal cancer, average procedure volume for the top five HVH increased from 36.6 to 60 cases/year from 2000 to 2006.

Adjusting for population-wide changes in organ site-specific procedure volume over time, the odds of surgery at a LVH decreased annually for esophageal (≤ 3/year) and pancreatic (≤ 4/year) procedures: per year odds ratio (OR) of 0.87 (95% CI, 0.85 to 0.90) and 0.85, respectively (95% CI, 0.84 to 0.87). There were small changes in the odds of having surgery at a LVH for colon (≤ 37/year) and rectal (≤ 11/year) cancer procedures, as well: per year OR 0.97 (95% CI 0.97 to 0.98) and 1.02 (95% CI, 1.01 to 1.03), respectively. Over the entire study period, this translated to substantial decreases in the likelihood of surgery at a LVH for esophageal (OR, 0.25) and pancreatic (OR, 0.20) procedures. In absolute terms, the number of esophagectomies performed at LVH (≤ 3/year) decreased from 36% (130 of 362) to 14% (92 of 681), and the number of pancreatectomies performed at LVH (≤ 4/year) decreased from 36% (280 of 777) to 12% (209 of 1,718).

Mortality

For the study area, in-hospital mortality for esophageal resections declined from 8.15% to 3.12% from 1996 to 2006 ($P = .038$). Similarly, in-hospital mortality for pancreatic resections declined from 7.31% to 3.84% ($P = .001$). In-hospital mortality declined from 3.33% to 2.64% ($P = .002$) for colon cancer surgery. Mortality for

Fig 2. Number of available high- or very high–volume hospitals. Total number of hospitals meeting 1996 quintile cut points for high- or very high–volume hospitals.

Table 1. Distance Traveled (miles) by Hospital Procedure Volume (1996 to 2006)

	Volume										
	Very Low		Low		Medium		High		Very High		
Organ	Median	IQ Range	Median	IQ Range	Median	IQ Range	Median	IQ Range	Median	IQ Range	P
Esophagus	3.6	1.7-9.9	6.2	2.5-14.6	11.4	4.4-30.7	22.7	9.0-46.0	29.8	13.4-57.5	< .001
Pancreas	3.5	1.6-8.3	4.7	2.1-9.9	7.0	3.0-18.0	13.4	6.3-30.4	20.4	9.6-43.4	< .001
Colon	3.2	1.3-8.3	3.3	1.5-8.1	4.3	1.9-9.3	4.6	2.1-9.1	5.9	2.9-11.9	< .001
Rectum	3.6	1.4-8.9	4.3	1.9-9.2	4.8	2.2-9.9	6.4	3.0-14.3	10.3	4.8-24.5	< .001

Abbreviation: IQ, interquartile.

rectal resections was very low and did not change significantly over time (1.84% in 1996, 1.57% in 2006; $P = .703$).

Travel Distance

Throughout the study period, travel distance was proportional to hospital procedure volume (Table 1). For each site, an increase in median travel distance, roughly proportional to the degree of centralization, was observed over time: esophagus 72% ($P < .001$), pancreas 40% ($P < .001$), colon 17% ($P < .001$), and rectum 28% ($P < .001$; Fig 3).

The 10.2% of patients (27,848 of 271,986) who lived in rural counties traveled further than other patients for all disease sites. In 1996 to 1997, rural patients traveled a median 35.9, 35.9, 5.4, and 6.2 miles further than nonrural patients for esophageal, pancreatic, colon, and rectal resections, respectively ($P < .001$ in all cases). In 2005 to 2006, the differences between rural and nonrural travel were 38.9, 35.9, 6.5, and 9.4 miles, respectively ($P < .001$ in all cases). The increasing effect of rurality on travel distance over time was significant for all sites, except pancreas (esophagus $P = .028$; pancreas $P = .977$; colon $P < .001$; rectum $P < .001$).

We performed additional analyses to examine whether the increase in travel distance could be attributed directly to centralization. The median distance traveled increased by 0.73 miles from 1996 to 1997 to 2005 to 2006 for rectal cancer ($P < .001$), 5.02 miles for esophageal cancer ($P < .001$), 3.14 miles for pancreatic cancer ($P < .001$), and 0.47 miles for colon cancer ($P < .001$). After controlling for treatment in the highest volume tercile, distance trav-

eled still increased by 0.83 miles for rectal cancer ($P < .001$), but only 1.16 miles for esophageal cancer ($P = .001$), and 0.25 miles for colon cancer. After controlling for treatment at a HVH, the median distance traveled for pancreatic cancer actually decreased 0.48 miles between 1996 to 1997 and 2005 to 2006 ($P = .025$). The attenuation of the year effect after controlling for volume was statistically significant in all cases ($P < .001$), providing strong evidence for a causal relationship between centralization and the increasing travel distance.

For each organ site, a substantial portion of patients (esophagus 14.8%, pancreas 13.3%, colon 22.6%, rectum 17.5%) treated at LVH or VLVH in 2006 traveled equal or further distance to reach that hospital than they would have had to travel to reach the nearest existing HVH or VHVH in the study area. The majority of patients (esophagus 54%, pancreas 59%, colon 62%, rectum 55%) who had surgery at a LVH or VLVH in 2006 could have reached an existing HVH or VHVH by traveling ≤ 10 additional miles. For patients treated at LVH and VLVH, the median travel distance to the nearest HVH or VHVH in the study area was less than 15.5 miles (esophagus 15.3, pancreas 12.5, colon 10.1, rectum 14.6 miles; Fig 4). Still, in 2006, a modest percentage of all patients from the study area lived ≥ 60 miles from the nearest HVH or VHVH. The less common the procedure, the greater the percentage of patients who lived ≥ 60 miles from the nearest HVH or VHVH: esophagus 11.9% (75 of 628), pancreas 9.0% (146 of 1,631), colon 1.4% (258 of 18,928), rectum 5.5% (217 of 3,925).

Disparities

For each organ site, there were differences in race, payer, socioeconomic status, and rurality between patients treated at LVH and those treated at higher volume hospitals (Table 2). In general, patients at LVH were more likely to be black, have Medicaid, Medicare, or no insurance, be from nonmetropolitan areas, and be from areas with higher poverty than patients treated at higher volume hospitals. No consistent pattern of improvement or deterioration over time could be identified.
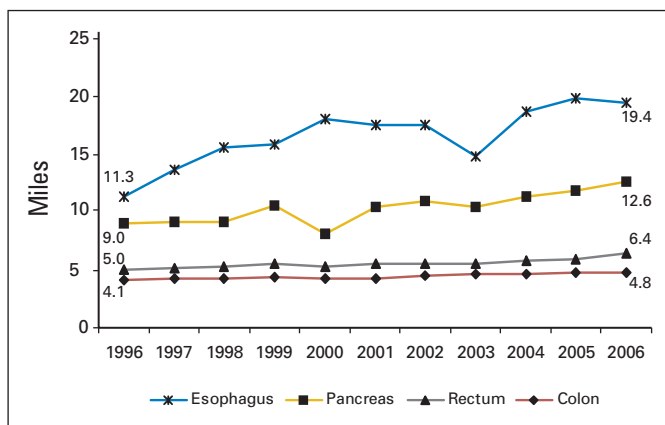
Fig 3. Travel distance over time. Median straight-line distance from patient zip code to treating facility in miles.

DISCUSSION

Centralization of cancer care has been documented to varying degrees throughout Canada and Europe,[31-34] but little information has previously been available regarding the degree to which cancer surgery has been centralized in the United States.[24-28] We demonstrated that over the past decade in the United States, the majority of procedures for
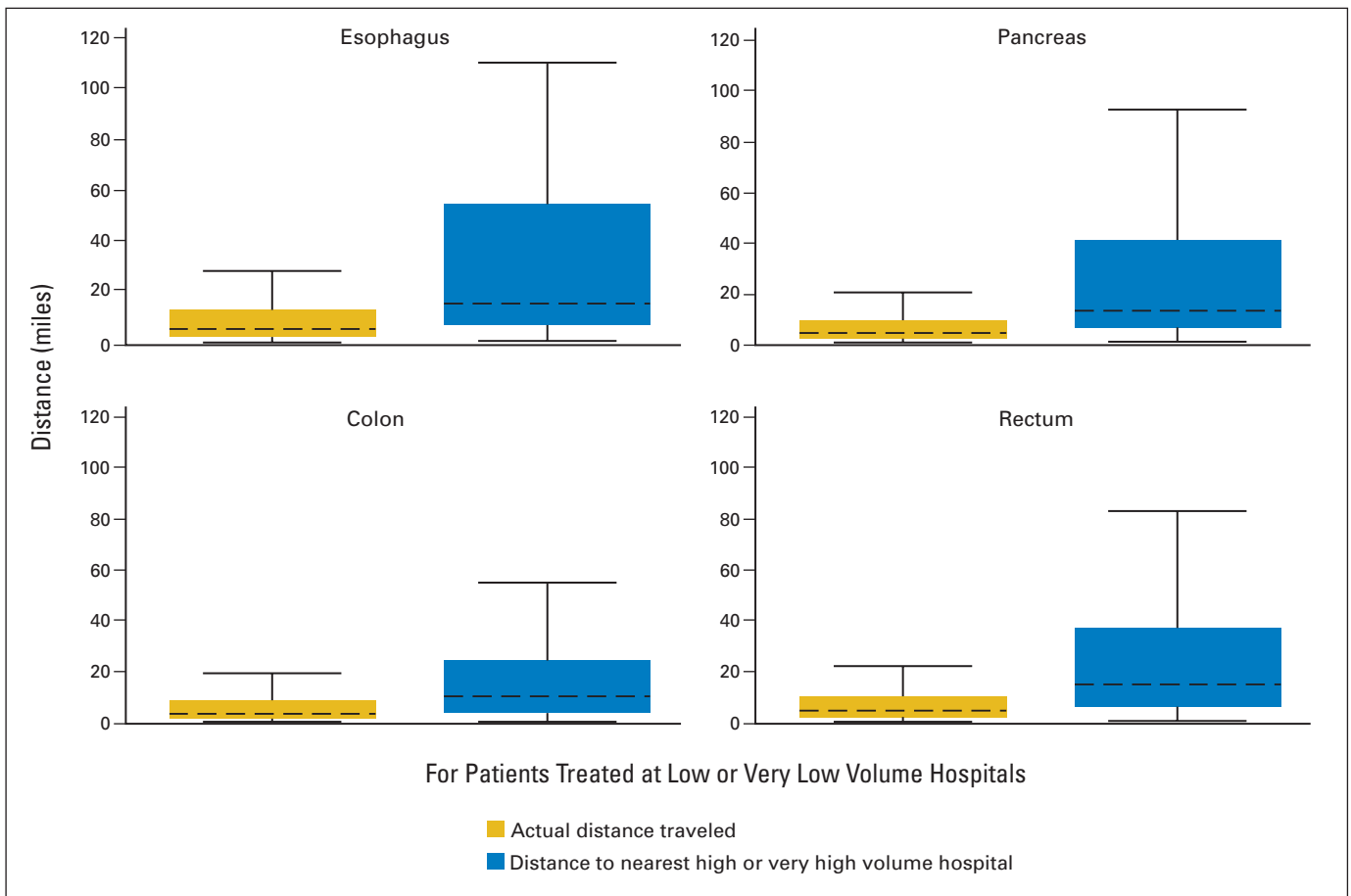
Fig 4. Difference between actual distances traveled and distances to nearest high volume hospital. Comparison of actual distances traveled to reach treating facility and distances to nearest high or very high volume hospital in 2006 for patients from NJ, NY, and PA who underwent surgery at a low or very low volume hospital in the study area. Dashed line represents median. Box represents interquartile (IQ) range. Outliers (values > 75th percentile + 1.5 × IQ range) were omitted from the graphic for ease of interpretation.

esophageal and pancreatic cancer have been centralized to HVH. Meanwhile for colorectal cancer, there has been little change.

The volume-outcome relationships for esophagectomy and pancreatectomy have received more consistent national and international attention than the volume-outcome relationships for colorectal surgery, possibly one explanation for the differing degrees to which these procedures have been centralized.[8,9,33,34] The focus of studies addressing the more complex procedures has been differences in perioperative mortality,[2,4,5,35,36] while most of the compelling data for colorectal surgery have addressed intermediate outcomes such as nodal yield,[17,37-39] complication rates,[40-42] length of stay,[41,42] ostomy rates,[17,37,42-44] and local recurrence rates.[43,45] Stakeholders have placed more emphasis on minimizing perioperative mortality than on improving other clinical outcomes.[8,9]

The degree to which cancer surgery has become centralized is likely dependent on many factors. For example, the scope of practice for surgeons, in general, is narrowing.[46] Less frequent, more complex operations are increasingly deferred to a small group of subspecialists, while more common operations, such as colectomy, remain the purview of a larger group of surgeons, including general surgeons, surgical oncologists, minimally invasive surgeons, and colorectal surgeons. As a result, surgeons, themselves, may be an influential force behind the degree to which cancer care is centralized.

Other difficult to quantify factors also contribute to the process. Health care systems encourage referral to in-system providers as a means of maintaining market share; physicians establish referral patterns, based on factors such as ease of referral and likelihood of retaining patients after surgery; and, payers designate preferred in-network providers. Each of these factors may alternately promote or impede referral to HVH depending on the situation. Ultimately, individual patient choice is only one of many factors influencing where a procedure is performed, and quality improvement initiatives need to be targeted accordingly.

An unresolved issue is the question of where to set the bar.[47,48] Studies have been unable to determine threshold volumes above which outcomes are generally regarded as acceptable. While few would contend that one to two esophagectomies or pancreatectomies per year is adequate volume, it is possible that eight proctectomies or 25 colectomies may be sufficient, even though these numbers would have placed hospitals in the very low volume category for this study. In addition, which clinical outcomes should be used to determine benchmark volume standards needs to be determined. While perioperative mortality is easy to study and suitable for some procedures, other outcomes (ie, local control or morbidity) may be more appropriate for procedures with low expected mortality. The Leapfrog group set volume standards for pancreatectomy (11/year) and esophagectomy

	Rectum		Colon		Esophagus		Pancreas	
Variable	1996 to 1997	2005 to 2006	1996 to 1997	2005 to 2006	1996 to 1997	2005 to 2006	1996 to 1997	2005 to 2006
Metropolitan								
Yes	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Non-metropolitan	4.42*†	2.86*†	4.54*	4.95*	0.70	1.07	1.62‡	0.86
Race								
White	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Black	1.47§	1.48*	1.36*	1.36*	0.93‖	3.22*‖	1.61‖	2.16*‖
Asian	0.89	0.72	0.96	1.29‡	0.50	1.25	1.60	0.89
Unknown	1.29*¶	0.97¶	0.83*†	1.26*†	0.93	1.17	1.42§	1.18
Insurance								
Private insurance	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Medicaid	2.20*	2.01*	1.96*	1.97*	1.39	1.82	3.61*	2.78*
Medicare	1.26*	1.44*	1.26*	1.31*	1.39	1.58‡	1.27‡	1.35‡
Uninsured	2.34*	1.70‡	2.57*¶	3.85*¶	2.42	2.71	3.22§	4.51*
Unknown insurance	1.08‖	1.94§‖	1.97*	1.83*	1.28	2.59	0.55	3.04§
Sex								
Female	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Male	1.09	1.04	0.99	1.02	0.95	0.74	0.94	1.09
Poverty, %#								
0-5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6-20	1.46*	1.50*	1.70*	1.69*	1.23	1.61‡	1.26	1.38‡
> 20%	1.68*	1.72*	1.71*†	2.23*†	3.20*	2.39§	0.86	1.13

Table 2. Sociodemographic Differences in Odds Ratios of Having Surgery at Low Volume Hospital

NOTE. Multivariable analysis examining odds of having surgery at a low volume hospital (1996 tercile cutpoints) in 1996 to 1997 compared with 2005 to 2006 for various sociodemographic factors.
*Odds ratio is significant ($P \leq .001$) compared to referent category for given site and year.
†Change in odds ratio for category is significant ($P \leq .001$) over time for given site.
‡Odds ratio is significant ($P \leq .05$) compared to referent category for given site and year.
§Odds ratio is significant ($P \leq .01$) compared to referent category for given site and year.
‖Change in odds ratio for category is significant ($P \leq .05$) over time for given site.
¶Change in odds ratio for category is significant ($P \leq .01$) over time for given site.
#Percentage of residents in census tract living at or below 100% poverty line.

(13/year).[9] If national quality initiatives set similar volume standards for colorectal surgery, increased centralization of these more common procedures might ensue. In contrast, if studies demonstrate that the bar does not need to be set high to achieve acceptable clinical outcomes, then adequate volume may be achieved by many hospitals without the need for major changes in cancer care delivery. Until validated minimum volume standards are established, the need for and appropriateness of further centralization cannot be fully assessed.

Previous studies speculate about changes in travel distance using existing hospital volume and location measurements. These methods do not account for changes in hospital volume over time and may underestimate or misjudge the quantity and distribution of HVH.[21,49,50] In this observational study, we documented that the number of hospitals meeting HVH criteria changed considerably over time. However, even with significant increases in HVH, overall travel distance for pancreas and esophageal cancer patients increased substantially with centralization. While most patients remaining at LVH could reach an existing HVH with little to no increase in travel, there are a modest number of patients who travel or would have to travel very long distances (≥ 60 miles) to reach the nearest HVH. Thus far, travel distance has not prevented centralization of esophagectomy or pancreatectomy, but the implications of increasing distance should not be ignored. Even small increases in distance may impose a substantial barrier for subsets of the population. As the cost of travel increases, the extent to which travel distance serves as a barrier to cancer care is likely to increase.

Centralization has the potential to introduce a capacity problem. To accommodate more patients at HVH without increasing wait times, existing HVH need to increase capacity or new HVH need to be developed. Figure 2 demonstrates that for esophageal and pancreatic cancer, the number of HVH is increasing. Meanwhile the caseload of the existing HVH also increased over time. Although wait times need to be monitored, previous work suggests that extensive centralization is possible without increases in wait time.[32]

As reported in previous studies, the majority of patients remaining at LVH could reach an existing HVH with minimal increase in travel distance.[49] Other barriers aside from travel distance have been consistently demonstrated.[2,13-19] We found marked differences in race, socioeconomic status, and payer among patients treated at HVH versus LVH. We hypothesized that centralization would exacerbate existing disparities as empowered patients shifted to HVH leaving only disadvantaged patients at LVH, where volume would decrease further over time. While the data do not support this a priori hypothesis, the significance of existing disparities should not be understated.

Our study included all hospital discharges for a large geographically diverse area. Consequently, we were able to study shifts in patterns of care over time. Since the examined area was a large, contiguous geographic region with little border crossing, the influence of adjacent, noncaptured centers was negligible. While these are strengths of the data, there are limitations. For example, only 10% of our study population lived in counties designated as rural. As a result,

this study may underestimate the impact of centralization on travel distance for patients from more rural areas of the country.

Since discharge data do not provide staging information, we were unable to examine the likelihood of receiving standard of care therapy. It is possible that patients facing long travel distances may have been more likely to forgo or delay surgery. Since only patients who underwent surgical resection were examined, this study cannot completely assess the degree to which travel burden served as a barrier to care.

Straight-line distance is an adequate proxy for travel time,[52,53] but these measurements are known to underestimate road distance by at least 20% to 30%.[29,54] Examining a random sample of all patients from our study, we estimate that straight-line distance underestimated true travel distance by 35% to 40%. Consequently, for this study, travel distance should be viewed in terms of relative mileage differences and percent change over time, rather than absolute mile measurements.

This study was not designed to identify a causal relationship between centralization of cancer surgery and clinical outcomes. As a result, one cannot know whether population-wide improvements in perioperative mortality are due directly to centralization of care. However, there have been significant improvements in in-hospital mortality for complex cancer procedures coincident with increasing centralization of cancer surgery, and it is quite plausible that these gains are attributable to centralization.

Although there is no uniform consensus regarding what surgical volumes are sufficient for adequate clinical outcomes, the wealth of published literature supports a relevant relationship between procedure volume and outcomes for cancer surgery. Accordingly, there has been extensive centralization of complex cancer surgery over the past decade. Centralization continues without evidence of remitting. While this process can be expected to result in population level improvements in cancer outcomes, centralization is substantially increasing the travel distance for patients with cancer. Thus far, travel burden has not prevented centralization of complex cancer surgery; however, the impact of increasing travel distances needs to be monitored. The persistence of other sociodemographic barriers to HVH also needs to be addressed. The challenge remains to find ways to improve access to high quality cancer care for all patients.

AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

The author(s) indicated no potential conflicts of interest.

AUTHOR CONTRIBUTIONS

Conception and design: Karyn B. Stitzenberg, Neal J. Meropol
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REFERENCES

1. Luft HS, Bunker JP, Enthoven AC: Should operations be regionalized? The empirical relation between surgical volume and mortality. N Engl J Med 301:1364-1369, 1979

2. Birkmeyer JD, Siewers AE, Finlayson EV, et al: Hospital volume and surgical mortality in the United States. N Engl J Med 346:1128-1137, 2002

3. Birkmeyer JD, Sun Y, Wong SL, et al: Hospital volume and late survival after cancer surgery. Ann Surg 245:777-783, 2007

4. Begg CB, Cramer LD, Hoskins WJ, et al: Impact of hospital volume on operative mortality for major cancer surgery. JAMA 280:1747-1751, 1998

5. Lieberman MD, Kilburn H, Lindsey M, et al: Relation of perioperative deaths to hospital volume among patients undergoing pancreatic resection for malignancy. Ann Surg 222:638-645, 1995

6. Flood AB, Scott WR, Ewy W: Does practice make perfect? Part I: The relation between hospital volume and outcomes for selected diagnostic categories. Med Care 22:98-114, 1984

7. Balzano G, Zerbi A, Capretti G, et al: Effect of hospital volume on outcome of pancreaticoduodenectomy in Italy. Br J Surg 95:357-362, 2008

8. Hewitt M, Petitti D: Interpreting the Volume-Outcome Relationship in the Context of Cancer Care. Washington, DC, National Academies Press, 2001, pp 32

9. The Leapfrog Group: Evidenced Based Hospital Referral. Washington, DC, The Leapfrog Group c/o Academy Health, 2008, pp 1-3

10. van Lanschot JJ, Hulscher JB, Buskens CJ, et al: Hospital volume and hospital mortality for esophagectomy. Cancer 91:1574-1578, 2001

11. Topal B, Van de Sande S, Fieuws S, et al: Effect of centralization of pancreaticoduodenectomy on nationwide hospital mortality and length of stay. Br J Surg 94:1377-1381, 2007

12. Epstein AM: Volume and outcome: It is time to move ahead. N Engl J Med 346:1161-1164, 2002

13. Schrag D, Cramer LD, Bach PB, et al: Influence of hospital procedure volume on outcomes following surgery for colon cancer. JAMA 284:3028-3035, 2000

14. Schrag D, Panageas KS, Riedel E, et al: Hospital and surgeon procedure volume as predictors of outcome following rectal cancer resection. Ann Surg 236:583-592, 2002

15. Sosa JA, Bowman HM, Gordon TA, et al: Importance of hospital volume in the overall management of pancreatic cancer. Ann Surg 228:429-438, 1998

16. Harmon JW, Tang DG, Gordon TA, et al: Hospital volume can serve as a surrogate for surgeon volume for achieving excellent outcomes in colorectal resection. Ann Surg 230:404-411, 1999; discussion 411-413, 1999

17. Hodgson DC, Zhang W, Zaslavsky AM, et al: Relation of hospital volume to colostomy rates and survival for patients with rectal cancer. J Natl Cancer Inst 95:708-716, 2003

18. Morris AM, Wei Y, Birkmeyer NJ, et al: Racial disparities in late survival after rectal cancer surgery. J Am Coll Surg 203:787-794, 2006

19. Liu JH, Zingmond DS, McGory ML, et al: Disparities in the utilization of high-volume hospitals for complex surgery. JAMA 296:1973-1980, 2006

20. Ward MM, Jaana M, Wakefield DS, et al: What would be the effect of referral to high-volume hospitals in a largely rural state? J Rural Health 20:344-354, 2004

21. Dimick JB, Finlayson SR, Birkmeyer JD: Regional availability of high-volume hospitals for major surgery. Health Aff (Millwood) Web Exclusives: VAR45-VAR53, 2004 (suppl)

22. Finlayson EV, Birkmeyer JD: Effects of hospital volume on life expectancy after selected cancer operations in older adults: A decision analysis. J Am Coll Surg 196:410-417, 2003

23. Effective health care: Hospital volume and health care outcomes, costs and patient access. NHS Centre for Reviews and Dissemination 2:1-14, 1996

24. Riall TS, Eschbach KA, Townsend CM Jr, et al: Trends and disparities in regionalization of pancreatic resection. J Gastrointest Surg 11:1242-1251, 2007; discussion 1251-1252, 2007

25. Ho V, Heslin MJ, Yun H, et al: Trends in hospital and surgeon volume and operative mortality for cancer surgery. Ann Surg Oncol 13:851-858, 2006

26. Gordon TA, Bowman HM, Tielsch JM, et al: Statewide regionalization of pancreaticoduodenectomy and its effect on in-hospital mortality. Ann Surg 228:71-78, 1998

27. Goodney PP, Siewers AE, Stukel TA, et al: Is surgery getting safer? National trends in operative mortality. J Am Coll Surg 195:219-227, 2002

28. McPhee JT, Hill JS, Whalen GF, et al: Perioperative mortality for pancreatectomy: A national perspective. Ann Surg 246:246-253, 2007

29. Fortney J, Rost K, Warren J: Comparing alternative methods of measuring geographic access to health services. Health Serv Outcomes Res Methodol 1:173-184, 2000

30. Reference deleted

31. Al-Sarira AA, David G, Willmott S, et al: Oesophagectomy practice and outcomes in England. Br J Surg 94:585-591, 2007

32. Forshaw MJ, Gossage JA, Stephens J, et al: Centralisation of oesophagogastric cancer services: Can specialist units deliver? Ann R Coll Surg Engl 88:566-570, 2006

33. Langer B: Role of volume outcome data in assuring quality in HPB surgery. HPB (Oxford) 9:330-334, 2007

34. van Heek NT, Kuhlmann KF, Scholten RJ, et al: Hospital volume and mortality after pancreatic resection: A systematic review and an evaluation of intervention in the Netherlands. Ann Surg 242:781-788, 2005; discussion 788-790, 2005

35. Patti MG, Corvera CU, Glasgow RE, et al: A hospital's annual rate of esophagectomy influences the operative mortality rate. J Gastrointest Surg 2:186-192, 1998

36. Glasgow RE, Mulvihill SJ: Hospital volume influences outcome in patients undergoing pancreatic resection for cancer. West J Med 165:294-300, 1996

37. Meyerhardt JA, Tepper JE, Niedzwiecki D, et al: Impact of hospital procedure volume on surgical operation and long-term outcomes in high-risk curatively resected rectal cancer: Findings from the Intergroup 0114 study. J Clin Oncol 22:166-174, 2004

38. Miller EA, Woosley J, Martin CF, et al: Hospital-to-hospital variation in lymph node detection after colorectal resection. Cancer 101:1065-1071, 2004

39. Rogers SO Jr, Wolf RE, Zaslavsky AM, et al: Relation of surgeon and hospital volume to processes and outcomes of colorectal cancer surgery. Ann Surg 244:1003-1011, 2006

40. Farber BF, Kaiser DL, Wenzel RP: Relation between surgical volume and incidence of postoperative wound infection. N Engl J Med 305:200-204, 1981

41. Kuhry E, Bonjer HJ, Haglind E, et al: Impact of hospital case volume on short-term outcome after laparoscopic operation for colonic cancer. Surg Endosc 19:687-692, 2005

42. Marusch F, Koch A, Schmidt U, et al: Hospital caseload and the results achieved in patients with rectal cancer. Br J Surg 88:1397-1402, 2001

43. Ptok H, Marusch F, Kuhn R, et al: Influence of hospital volume on the frequency of abdominoperineal resection and long-term oncological outcomes in low rectal cancer. Eur J Surg Oncol 33:854-861, 2007

44. Simons AJ, Ker R, Groshen S, et al: Variations in treatment of rectal cancer: The influence of hospital type and caseload. Dis Colon Rectum 40:641-646, 1997

45. Wibe A, Eriksen MT, Syse A, et al: Effect of hospital caseload on long-term outcome after standardization of rectal cancer surgery at a national level. Br J Surg 92:217-224, 2005

46. Stitzenberg KB, Sheldon GF: Progressive specialization within general surgery: Adding to the complexity of workforce planning. J Am Coll Surg 201:925-932, 2005

47. Metzger R, Bollschweiler E, Vallbohmer D, et al: High volume centers for esophagectomy: What is the number needed to achieve low postoperative mortality? Dis Esophagus 17:310-314, 2004

48. Christian CK, Gustafson ML, Betensky RA, et al: The Leapfrog volume criteria may fall short in identifying high-quality surgical centers. Ann Surg 238:447-455, 2003; discussion 455-457, 2003

49. Birkmeyer JD, Siewers AE, Marth NJ, et al: Regionalization of high-risk surgery and implications for patient travel times. JAMA 290:2703-2708, 2003

50. Dudley RA, Johansen KL, Brand R, et al: Selective referral to high-volume hospitals: Estimating potentially avoidable deaths. JAMA 283:1159-1166, 2000

51. Reference deleted

52. Phibbs CS, Luft HS: Correlation of travel time on roads versus straight line distance. Med Care Res Rev 52:532-542, 1995

53. McGuirk MA, Porell FW: Spatial patterns of hospital utilization: The impact of distance and time. Inquiry 21:84-95, 1984

54. Williams AP, Schwartz WB, Newhouse JP, et al: How many miles to the doctor? N Engl J Med 309:958-963, 1983

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