Original Article

Fragmentation in Specialist Care and Stage III Colon Cancer

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BACKGROUND: Patients with cancer frequently transition between different types of specialists and across care settings. This study explored how frequently the surgical and medical oncology care of stage III colon cancer patients occurred across more than 1 hospital and whether this was associated with mortality and costs. **METHODS:** This was a retrospective Surveillance, Epidemiology, and End Results–Medicare cohort study of 9075 stage III colon cancer patients diagnosed between 2000 and 2009 who had received both surgical and medical oncology care within 1 year of their diagnosis. Patients were assigned to the hospital at which they had undergone their cancer surgery and to their oncologist's primary hospital, and then they were characterized according to whether these hospitals were the same or different. Outcomes included all-cause mortality, subhazards for colon cancer–specific mortality, and costs of care at 12 months. **RESULTS:** Thirty-seven percent of the patients received their surgical and medical oncology care from different hospitals. Rural patients were less likely than urban patients to receive medical oncology care from the same hospital (odds ratio, 0.62; 95% confidence interval, 0.43-0.90). Care from the same hospital was not associated with reduced all-cause or colon cancer–specific mortality but resulted in lower costs (8% of the median cost) at 12 months (dollars saved, $5493; 95% confidence interval, $1799-$9525). **CONCLUSIONS:** The delivery of surgical and medical oncology care at the same hospital was associated with lower costs; however, reforms seeking to improve outcomes and lower costs through the integration of complex care will need to address the significant proportion of patients receiving care at more than 1 hospital. ***Cancer* 2015;121:3316-24.** *© 2015 American Cancer Society.*

KEYWORDS: colon cancer, delivery of health care, health care costs, integrated health care systems, mortality, patient care management.

INTRODUCTION

Fragmentation of care is a central cause of poor quality and high costs in the United States.[1,2] Because of its resource intensity, complexity for patients, and inequities in quality, cancer care has been identified by the Institute of Medicine as a priority area for addressing care fragmentation.[3] One strategy for reducing fragmentation involves improving continuity during transitions in care, that is, junctures at which a patient's care switches between providers, settings, or institutions.[3,4] Many current health care reforms, including accountable care organizations, seek to create continuity during transitions by developing integrated networks of providers and institutions to deliver complex care.[5]

At the same time, more cancer patients are receiving care from high-volume surgeons located at a few high-volume regional surgical centers.[6,7] Patients who travel to a hospital for surgical care while they are receiving oncologic care from a different local hospital may experience increased fragmentation. In some settings, receiving treatment for an illness from more than 1 hospital is associated with poorer outcomes and delays in care.[8,9]

For most cancer care, transitioning between specialists (ie, a surgeon and a oncologist) and settings (ie, inpatient and outpatient settings) is inevitable. However, it is plausible that patient outcomes and costs may improve when cancer patients receive 1-hospital care, that is, surgical and oncologic care delivered at the same hospital. One-hospital care may ease the coordination of follow-up care, decrease barriers to physician communication, and reduce redundancy in care. The effect of this type of care fragmentation (1-hospital care vs 2-hospital care) on cancer mortality and costs of care is unknown.

Stage III colon cancer provides an important model for examining fragmentation due to 2-hospital care. Colorectal cancer is the second most expensive cancer and the third leading cause of cancer mortality in the United States.[10]

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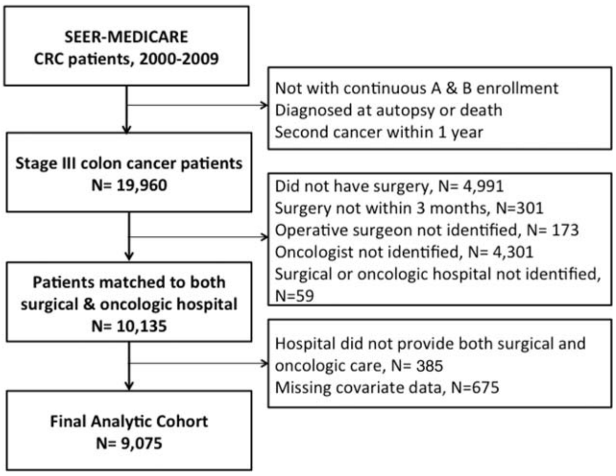

Figure 1. Flowchart of inclusions and exclusions for the analytic cohort. CRC indicates colorectal cancer; SEER, Surveillance, Epidemiology, and End Results.

Furthermore, guidelines for stage III colon cancer recommend timely surgery and adjuvant chemotherapy to improve survival.[11] Because this requires coordination between 2 separate providers across different settings (inpatient surgical care and outpatient medical oncology care) and possibly at different institutions, patients with stage III colon cancer are particularly vulnerable to care fragmentation. Indeed, a significant proportion of patients do not receive guideline-concordant care, and disparities exist.[11]

To evaluate the association between care fragmentation and outcomes for stage III colon cancer, we examined the associations between 1- and 2-hospital care and overall survival, colon cancer–specific survival, and 12-month costs of care.

MATERIALS AND METHODS

Study Population

We used Surveillance, Epidemiology, and End Results (SEER)–Medicare files for patients with colon cancer who were diagnosed between 2000 and 2009. The SEER-Medicare database is a population-based cancer registry encompassing approximately 28% of the US population, and it is linked to claims for approximately 93% of patients with Medicare.[12]

Patients with continuous Part A and B Medicare coverage during the 12 months before and after the diagnosis date were eligible for inclusion. Patients were excluded if they were younger than 66 years, were enrolled in a health maintenance organization during the 2-year interval, were diagnosed at autopsy or death, were diagnosed with a second cancer within 12 months of the colon cancer diagnosis, were lacking information for covariates, were not stage III, or could not be assigned to their surgeons, oncologists, and surgical/oncologic hospitals. We included only patients receiving care at hospitals capable of providing both surgical and oncologic care (ie, hospitals that had both medical oncology and surgical claims associated with them in a given year). The final analytic cohort consisted of 9075 patients (Fig. 1).

Measures

Outcomes

The primary outcome was all-cause mortality; survival time was calculated from the date of the colon cancer diagnosis to the Medicare date of death or the censor date of December 31, 2011. Colon cancer–specific mortality was a secondary outcome; the censor date was December 31, 2009 because the cause of death was not available after this date. We also examined the total cost of care 12 months after diagnosis, which was calculated with inpatient claims (Medicare Provider Analysis and Review file), physician fees (Carrier Claims file), and outpatient claims (Outpatient Statistical Analysis file).

Provider and Hospital Assignment

For surgical care, the operative surgeon was identified as the patient's surgeon, and the location of the procedure was the patient's surgical hospital. For the 713 patients (7.9%) who had more than 1 colon cancer surgery, the assignment of surgical care was based on the first operation. For oncologic care, we assigned patients to the medical oncologists who billed for the plurality of their visits in the year following their diagnosis (using Berenson-Eggers Type of Service codes M1-M6 to identify appropriate claims and specialty codes 83 and 90), and then we designated the hospital at which these oncologists were most likely to practice.[13] In accordance with Bynum et al's approach,[14] oncologists were assigned to the hospital at which they billed for the most inpatient care. Oncologists who did not bill any inpatient claims were assigned to the hospital to which most of their patients were admitted. Patients were classified as experiencing 1-hospital care if they underwent their operation at the hospital to which their oncologist was assigned, and they were classified as receiving 2-hospital care if the hospitals were different.

Patient-Level Covariates

Covariates included the following: age, sex, self-reported Medicare race (black, white, or other), census tract median household income (in quartiles), year of diagnosis, Charlson comorbidity score in the 12 months before diagnosis, urban/rural residence, and SEER site. Cancer characteristics included the following: tumor grade, adequate lymph node resection during surgery (≥12 lymph nodes), and, for patients diagnosed in 2004 and onward, cancer substage.[15]

Physician-Level Covariates

The yearly surgical volume was tabulated with the total number of all colon cancer patients on whom surgeons operated in a given year,[16] and it was modeled in quartiles (<2, 2, 3, and >3 cases per year). Similarly, the yearly panel size of all colon cancer patients attributed to each medical oncologist was calculated and modeled in quartiles (<2, 2 or 3, 4 or 5, and >5 cases per year).

Hospital-Level Covariates

Hospital characteristics from SEER included National Cancer Institute–recognized status, academic hospital status, and for-profit status. We determined the volume of patients who underwent colon cancer surgery at each hospital by summing the total number of all colon cancer patients between 2000 and 2009. The hospital volume was analyzed in quartiles with the following cutoffs: 0 to 111, 112 to 198, 199 to 312, and >312 cases for surgical hospital volumes and <130, 130 to 210, 211 to 320, and >320 cases for oncologic hospital volumes.[16,17]

Analysis

Multivariate logistic regression controlling for patient, provider, and hospital characteristics was performed to identify characteristics independently associated with 1-hospital care versus 2-hospital care. A survival analysis for all-cause mortality was conducted with Cox proportional hazards models. Fine and Gray's method for competing risk regression was used to model mortality due to colon cancer, and death from other causes was a competing risk.[18] To assess the proportional hazards assumption, we used a test of a nonzero slope.[19]

Our cost analyses estimated the difference in costs between those receiving 1-hospital care and those receiving 2-hospital care with generalized linear models. Using modified Park tests to determine the distribution and link function,[20] we modeled nonextreme costs (the bottom 95% of patient costs) with a gamma variance distribution and extreme costs (top 5%) with an inverse Gaussian variance distribution. All dollar values were inflated to 2009 values with the annual gross domestic product price index.[21]

For both survival and cost modeling, we used propensity-matched, doubly robust regression models. Propensity scores were modeled as a function of all patient, physician, and hospital characteristics with psmatch2 (version 3.0) in Stata.[22] Balance was optimized with 1:1 nearest neighbor matching using a caliper size of 0.01 without replacement. To retain equivalence between patients with 1-hospital care and patients with 2-hospital care, hospital characteristics were coded twice (once as the surgical hospital and once as the oncologic hospital) for patients receiving 1-hospital care. We corrected for clustering with generalized estimating equations and robust standard errors. The clustering unit was the medical-surgical hospital pair at which patients received care.

We performed sensitivity analyses to ensure the robustness of our findings. First, we modeled all analyses by controlling for substages in the subcohort of patients diagnosed in 2004 and onward. Second, we modeled the total cost of care at 6 months and costs at both 6 and 12 months only for those surviving to each time. Third, because physician and hospital characteristics may have been unknown to patients before they received their care, we reran our propensity models but included only patient characteristics. Fourth, with known disparities, we tested for interactions between hospital care and race/ethnicity, median census tract income, and urban/rural residence. Fifth, we ran analyses excluding those patients with more than 1 surgery to avoid a misclassification bias.

Data were analyzed with Stata IC 12.1. Our study received approval from the institutional review board of the Johns Hopkins University School of Medicine.

RESULTS

In our cohort of 9075 patients, 37% received 2-hospital care; that is, they received their medical oncology care from an oncologist not assigned to their surgical hospital (Table 1). Patients in rural areas (population < 250,000) were less likely to receive 1-hospital surgical and medical oncology care than those in large cities (odds ratio, 0.62; 95% confidence interval [CI], 0.43-0.90). Patients who received care from higher volume surgeons or from higher volume surgical hospitals were significantly more likely to receive 1-hospital care than those who received their surgical care from lower volume counterparts.

As shown in Figures 2 and 3, there were no significant differences in all-cause mortality or colon cancer–specific mortality between patients receiving 1-hospital care and patients receiving 2-hospital care. The average

TABLE 1. Characteristics of Stage III Colon Cancer Patients Categorized by the Receipt of 1-Hospital Medical Oncology and Surgical Care Versus 2-Hospital Medical Oncology and Surgical Care

	1-Hospital Care (n = 5758 or 63.45%)	2-Hospital Care (n = 3317 or 36.55%)	*P*	OR (95% CI) for Receiving 1-Hospital Care[a]
Patient-level predictors				
Age, No. (%)				
>65-70 y	941 (16.3)	524 (15.8)	.066	Reference
71-75 y	1303 (22.6)	807 (24.3)		0.92 (0.79-1.07)
76-80 y	1473 (25.6)	896 (27.0)		0.92 (0.80-1.07)
81-85 y	1256 (21.8)	677 (20.4)		1.02 (0.88-1.18)
≥86 y	785 (13.6)	413 (12.5)		1.04 (0.87-1.24)
Female, No. (%)	3282 (57.0)	1886 (56.9)	.73	0.99 (0.90-1.09)
Race, No. (%)				
White	5003 (86.9)	2778 (84.1)	<.001	Reference
Black	427 (7.4)	263 (7.9)		1.07 (0.86-1.33)
Other	328 (5.7)	266 (8.0)		0.82 (0.64-1.05)
Census tract median income, No. (%)				
Lowest quartile	1369 (23.8)	1052 (31.7)	<.001	Reference
2nd quartile	1345 (23.4)	829 (25.0)		1.04 (0.88-1.22)
3rd quartile	1390 (24.1)	721 (21.7)		1.09 (0.90-1.31)
Highest quartile	1654 (28.7)	715 (21.6)		1.20 (0.97-1.47)
Urban/rural residence, No. (%)				
≥1,000,000 people	3409 (59.2)	1689 (50.9)	<.001	Reference
≥250,000 to <1,000,000 people	1679 (29.2)	880 (26.5)		0.91 (0.66-1.25)
<250,000 people	670 (11.6)	748 (22.6)		0.62 (0.43-0.90)
Charlson comorbidity score, No. (%)				
0	3226 (56.0)	1854 (55.9)	.89	Reference
1	1435 (24.9)	840 (25.3)		1.02 (0.92-1.14)
≥2	1097 (19.1)	623 (18.8)		1.07 (0.95-1.21)
Tumor grade, No. (%)				
Well differentiated	301 (5.2)	162 (4.9)	.099	Reference
Moderately differentiated	3601 (62.5)	2131 (64.2)		0.87 (0.68-1.13)
Poorly differentiated	1716 (29.8)	966 (29.1)		0.85 (0.65-1.12)
Undifferentiated	140 (2.4)	58 (1.8)		1.20 (0.78-1.84)
Adequate lymph node resection, No. (%)				
<12	2000 (34.7)	1237 (37.3)	.014	Reference
≥12	3758 (65.3)	2080 (62.7)		0.97 (0.86-1.09)
Substage, No. (%)[b]				
IIIA	368 (10.5)	205 (10.3)	.96	Reference
IIIB	1993 (56.8)	1134 (57.2)		0.99 (0.81-1.20)
IIIC	1146 (32.7)	623 (32.4)		0.99 (0.81-1.22)
Provider-level characteristics				
Yearly surgical volume, No. (%)				
Lowest quartile	1161 (20.2)	901 (27.2)	<.001	Reference
2nd quartile	1499 (26.0)	890 (26.8)		1.03 (0.88-1.10)
3rd quartile	1570 (27.3)	779 (23.5)		1.29 (1.14-1.40)
Highest quartile	1528 (26.5)	747 (22.5)		1.38 (1.02-1.77)
Yearly oncologist panel size, No. (%)				
Lowest quartile	1432 (24.9)	885 (26.7)	<.001	Reference
2nd quartile	1499 (26.0)	767 (23.1)		0.88 (0.69-1.21)
3rd quartile	1401 (24.3)	750 (22.6)		0.93 (0.77-1.15)
Highest quartile	1426 (24.8)	915 (27.6)		0.90 (0.72-1.13)
Hospital-level characteristics				
Volume of patients, No. (%)				
Surgical hospital			<.001	Reference
Lowest quartile	862 (15.0)	1305 (39.3)		
2nd quartile	1507 (26.2)	714 (21.5)		2.94 (2.20-3.94)
3rd quartile	1719 (29.9)	656 (19.8)		3.68 (2.59-5.23)
Highest quartile	1670 (29.0)	642 (19.4)		3.99 (2.51-6.33)
Medical oncology hospital			<.001	Reference
Lowest quartile	1095 (19.0)	1002 (30.2)		
2nd quartile	1529 (26.6)	822 (24.8)		0.98 (0.74-1.30)
3rd quartile	1531 (26.6)	724 (21.8)		0.91 (0.66-1.24)
Highest quartile	1603 (27.8)	769 (23.2)		0.86 (0.59-1.25)
NCI status, No. (%)				
Surgical hospital	134 (2.3)	126 (3.8)	<.001	0.52 (0.28-0.94)
Medical oncology hospital	134 (2.3)	103 (3.1)	.025	1.07 (0.59-1.94)

TABLE 1. *Continued*

	1-Hospital Care (n = 5758 or 63.45%)	2-Hospital Care (n = 3317 or 36.55%)	*P*	OR (95% CI) for Receiving 1-Hospital Care[a]
Academic center, No. (%)				
Surgical hospital	3202 (55.6)	1578 (47.6)	<.001	1.06 (0.79-1.42)
Medical oncology hospital	3202 (55.6)	1833 (55.3)	.75	0.83 (0.65-1.06)
For-profit status, No. (%)				
Surgical hospital	437 (7.6)	522 (15.7)	<.001	0.66 (0.48-0.91)
Medical oncology hospital	437 (7.6)	391 (11.8)	<.001	0.98 (0.70-1.37)
Outcome measures				
Deaths, No. (%)	3157 (54.8)	1892 (57.0)	.041	N/A
Total costs for 1st year of care, median (IQR)	$69,406 ($45,223-$115,287)	$73,908 ($46,615-$125,622)	.001[c]	N/A

Abbreviations: CI, confidence interval; IQR, interquartile range; N/A, not applicable; NCI, National Cancer Institute; OR, odds ratio.
[a] ORs were fully adjusted for all other variables listed here as well as the diagnosis year and Surveillance, Epidemiology, and End Results site, which are not shown.
[b] The sample was restricted to those diagnosed in 2004 and onward (for whom these data were available).
[c] Wilcoxon-Mann-Whitney test.

follow-up times for all-cause and colon cancer–specific mortality were 4.3 (total, 38,836 years) and 3.3 years (total, 29,807 years), respectively. The median unadjusted cost of care at 12 months was approximately $4500 lower for patients receiving 1-hospital care ($73,908 vs $69,406, $P = .001$).

Table 2 shows the final propensity score–matched, doubly robust Cox proportional hazards regression for all-cause mortality, the competing risks subhazard regression for colon cancer–specific mortality, and the total cost of care at 12 months. Appropriate balance was obtained for covariates (Table 3). Receiving 1-hospital medical oncology and surgical care versus 2-hospital care was not associated with all-cause mortality (hazard ratio, 0.97; 95% CI, 0.92-1.05) or colon cancer–specific mortality (subhazard ratio, 0.98; 95% CI, 0.89-1.07). However, patients with nonextreme costs who received 1-hospital care had significantly lower total costs than those who received 2-hospital care (dollars saved, $5493; 95% CI, $1799-$9525). In particular, we found a statistically significant savings in inpatient claims (dollars saved, $3076; 95% CI, $520-$4893) among those receiving 1-hospital care versus 2-hospital care; this included the inpatient costs of the primary surgery. There were no statistically significant savings in physician fees ($523; 95% CI, –$786 to $1702) or outpatient claims ($1041; 95% CI, –$628 to $2277). When we examined only those patients diagnosed in 2004 and onward to account for substages (Table 4), the total cost difference was even greater for 1-hospital care (dollars saved, $7531; 95% CI, $1783-$13,043).

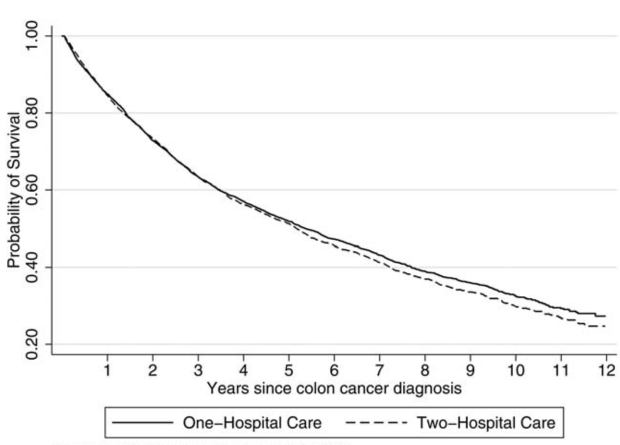

Figure 2. Kaplan-Meier survival curves for all-cause mortality: 1-hospital care versus 2-hospital care.

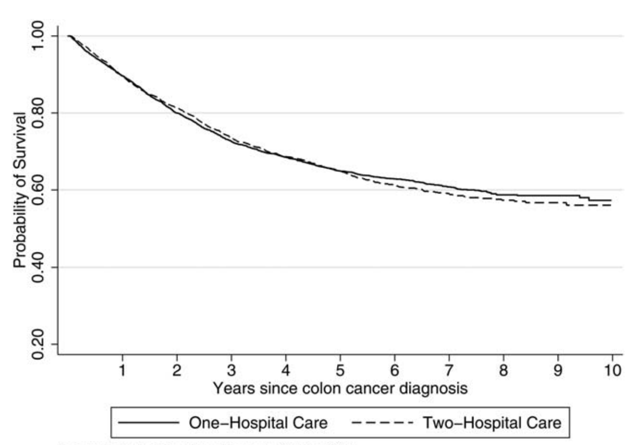

Figure 3. Kaplan-Meier survival curves for colon cancer–specific mortality: 1-hospital care versus 2-hospital care.

TABLE 2. All-Cause and Colon Cancer–Specific Mortality and Costs at 12 Months Associated With 1-Hospital Care Versus 2-Hospital Care From Propensity Score–Matched, Doubly Robust Models

	Hazard Ratio for All-Cause Mortality (n = 5482)[a]	Subhazard Ratio for Colon Cancer–Specific Mortality (n = 5482)[a]	Dollars Saved From Generalized Linear Model Estimates for Patients With Nonextreme Costs (n = 5186)[a b c]	Dollars Saved From Generalized Linear Model Estimates for Patients With Extreme Costs (n = 296)[a b c]
1-hospital care	Reference	Reference	Reference	Reference
2-hospital care	0.97 (0.92-1.05)	0.98 (0.89-1.07)	$5493 ($1799-$9525)	$23,244 (–$100,606 to $132,636)

[a] Ninety-five percent confidence intervals are shown in parentheses. Estimates are fully adjusted for all patient, provider, and hospital characteristics listed in Table 1 except for the substage (which is available only for those diagnosed in 2004 and onward).
[b] All dollar values were inflated to 2009 values with the annual gross domestic product price index.
[c] The patients with extreme costs were those patients whose costs were within the top 5%.

Notably, there were no cost savings among those patients with the most extreme costs (Table 2).

The results did not significantly change in any of the sensitivity analyses (Table 4), and all prespecified testing of statistical interactions terms was nonsignificant.

DISCUSSION

More than one-third of the patients with stage III colon cancer received their medical oncology care and surgical care from different hospitals. Although we did not observe significant differences in either all-cause or colon cancer–specific mortality related to this type of care fragmentation, we found significant differences in the 12-month cost of care. Patients receiving medical oncology care and surgical care at the same hospital had, on average, an 8% lower median cost than patients receiving 2-hospital care. These results raise important concerns regarding attempts to reduce cancer care fragmentation in the setting of current health care reform.

A substantial minority of patients received 2-hospital surgical and medical oncology care. Notably, rural residence was associated with receiving 2-hospital medical oncology and surgical care. This finding is consistent with known barriers to cancer care in rural communities, namely, limited access to physicians who provide colorectal cancer screening and treatment[23-25] and geographic distance to health care facilities.[24,25]

Because there is some evidence showing that more colon cancer patients are receiving surgical care at high-volume centers (which have been linked to improved outcomes), we had anticipated that patients would travel to receive high-volume surgical care but receive their medical oncology care from a different and potentially local hospital.[6,7,16,17,26] Instead, we found that patients who received surgery from high-volume surgeons or centers were more likely to receive 1-hospital care. With evidence suggesting that high-volume surgeons are more likely to collaborate in decisions about adjuvant chemotherapy with oncologists within their institution in comparison with lower volume surgeons,[27] patients may prefer to remain at a high-volume cancer center for their medical oncology care. A deeper understanding of why patients select certain providers and institutions is still needed to improve continuity during transitions in specialist care.

In contrast to our expectations, we did not observe differences in mortality between patients who received 1-hospital care or 2-hospital care in our study. Outcomes other than mortality such as process quality measures, delays in care, and satisfaction with care have been shown to vary with care fragmentation and warrant further study in the setting of 1-hospital cancer care versus 2-hospital cancer care.[8,9] Furthermore, informal connections between different hospitals, such as collaboration between providers and the emergence of patient navigators and care managers, may mitigate the mechanisms through which 2-hospital care potentially affects patient outcomes.[28,29]

We did observe lower costs among patients who received 1-hospital cancer care, and this suggests that perhaps less fragmented delivery of complex cancer care helps to reduce health care costs. Inpatient hospital costs in particular were significantly lower among those receiving 1-hospital care. These savings nearly doubled between 6 months and 1 year after the diagnosis, and this possibly reflects the fact that cost differences may be related to both early treatment and ongoing care or complications of early care. Single-hospital care delivery did not, however, decrease the expenditures of those patients with the most extreme costs. Further study is required to investigate the extent to which cost differences are driven by the length of the hospital stay, number of hospitalizations,

TABLE 3. Balance of Covariates After Propensity Score Matching

	1-Hospital Care, %	2-Hospital Care, %	Bias, %
Patient-level predictors			
Age			
>65-70 y	16.7	15.8	2.5
71-75 y	22.4	23.7	−2.8
76-80 y	26.8	26.7	0.6
81-85 y	21.3	20.9	0.8
≥86 y	12.8	13.1	−0.9
Female	58.7	57.2	2.8
Race			
White	83.9	84.1	−3.5
Black	8.0	7.5	1.8
Other	8.1	7.4	3.0
Census tract income			
Lowest quartile	29.2	27.5	3.8
2nd quartile	25.1	24.3	1.9
3rd quartile	21.5	23.5	−4.9
Highest quartile	24.2	24.7	−1.0
Urban/rural residence			
≥1,000,000 people	53.2	53.7	0.9
≥250,000 to <1,000,000 people	27.0	28.5	−3.2
<250,000 people	19.8	17.8	1.8
Charlson comorbidity score			
0	55.5	55.3	0.4
1	26.0	25.3	1.1
≥2	18.5	19.2	−1.7
Tumor grade			
Well differentiated	4.5	5.0	−2.2
Moderately differentiated	64.5	64.2	0.5
Poorly differentiated	28.8	28.9	−0.3
Undifferentiated	2.2	1.9	2.6
Adequate lymph node resection	64.2	63.9	0.5
Provider-level characteristics			
Yearly surgical volume			
Lowest quartile	24.4	23.9	1.4
2nd quartile	24.3	24.9	−1.7
3rd quartile	25.9	25.2	1.9
Highest quartile	25.4	26.0	−1.6
Yearly oncologist panel size			
Lowest quartile	24.3	24.9	−1.9
2nd quartile	25.0	25.6	−1.5
3rd quartile	24.8	24.2	1.8
Highest quartile	25.9	25.3	1.6
Hospital-level characteristics			
Volume of patients			
Surgical hospital			
Lowest quartile	28.5	27.1	3.4
2nd quartile	25.2	25.9	−1.7
3rd quartile	24.3	23.8	1.1
Highest quartile	22.0	23.2	−2.8
Medical oncology hospital			
Lowest quartile	32.6	30.3	4.3
2nd quartile	24.6	24.2	1.0
3rd quartile	21.9	22.1	−0.7
Highest quartile	21.0	23.4	−4.5
NCI status			
Surgical hospital	4.0	3.9	0.2
Medical oncology hospital	4.0	3.5	3.1
Academic center			
Surgical hospital	53.2	53.6	−0.8
Medical oncology hospital	53.2	53.7	−1.1
For-profit status			
Surgical hospital	13.2	11.8	4.7
Medical oncology hospital	13.2	11.4	5.2
Overall distribution of all covariates			
Before matching	—	—	8.06
After matching	—	—	2.75

Abbreviation: NCI, National Cancer Institute.
There was substantial improvement in the balance after we used 1:1 nearest neighbor matching without replacement and a caliper size of 0.01. The mean bias was less than 5% across nearly all covariates, and the overall mean bias for all covariates was reduced to 2.75 from 8.06 after propensity score matching.

preventable complications, duplication of services, or other factors. Electronic medical records and electronic referral systems, shared by physicians affiliated with the same hospital, have been associated with small but significant reductions in costs and improvements in timely care delivery and may have a role in explaining these findings, but to our knowledge, they have not been tested with respect to cancer care.[30,31]

There are limitations to our study. First, a large portion of medical oncology care occurs in outpatient settings, and oncologists may be affiliated with more than 1 hospital; both create challenges when one is trying to assign patients to hospitals. To test the face validity of our assignment method, we examined to which hospitals patients were admitted in the year following their diagnosis; 86% of the patients had the plurality of their inpatient admissions at the assigned oncologic hospital, and 93% had their admissions at either the assigned oncologic hospital or the assigned surgical hospital. Second, in line with previous studies,[32,33] a substantial proportion of the patients could not be assigned to a medical oncologist; we relied on specialty codes to identify physicians who were medical oncologists, and this could lead to misclassification if providers were missing a specialty code or were identified under an alternate specialty code. Third, because of concerns regarding the completeness of chemotherapy claims after changes in billing codes during the study period, we did not use the administration of chemotherapy to classify physicians as medical oncologists, nor could we confidently determine how 1-hospital care affected the timely receipt of chemotherapy. Fourth, some patients receiving care from 2 different hospitals may be part of a health system that coordinates care between hospitals. As of 2012, only 26% of registered US hospitals were part of such an integrated network.[34] Failing to account for these connections between hospitals would bias our findings toward the null. Fifth, we were unable to

TABLE 4. Sensitivity Analyses for Effect Estimates in Table 2 for 1-Hospital Care Versus 2-Hospital Care With Propensity Score–Matched, Doubly Robust Models

	Hazard Ratio for All-Cause Mortality[a]	Subhazard Ratio for Colon Cancer–Specific Mortality[a]	Dollars Saved on Costs at 12 mo[a,b]
Estimates from Table 2	0.97 (0.92-1.05)	0.98 (0.89-1.07)	$5493 ($1799-$9525)
Interaction terms with delivery of care			
White	Reference	Reference	Reference
Black	P = .16	P = .55	P = .23
Other ethnicity	P = .59	P = .49	P = .88
Interaction terms with delivery of care			
Lowest income quartile	Reference	Reference	Reference
2nd quartile	P = .86	P = .17	P = .30
3rd quartile	P = .93	P = .26	P = .48
Highest quartile	P = .85	P = .21	P = .27
Interaction terms with delivery of care			
1,000,000 people	Reference	Reference	Reference
≥250,000 to <1,000,000 people	P = .65	P = .93	P = .58
<250,000 people	P = .82	P = .24	P = .52
Adding substage to adjustment model[c]	1.02 (0.95-1.10)	0.97 (0.83-1.13)	$7531 ($1783-$13,043)
Cost of care at 12 mo for only those surviving to 12 mo	N/A	N/A	$5083 ($952-$9066)
Cost of care at 6 mo	N/A	N/A	$2832 ($747-$5470)
Cost of care at 6 mo for only those surviving to 6 mo	N/A	N/A	$2502 ($460-$5124)
Propensity score matching with only patient characteristics	0.99 (0.91-1.09)	1.03 (0.96-1.14)	$5023 ($1440-$8678)
Exclusion of patients with more than 1 surgery	0.98 (0.92-1.04)	0.99 (0.90-1.09)	$3861 ($733-$6891)

Abbreviation: N/A, not applicable.
[a] Ninety-five percent confidence intervals are shown in parentheses. Estimates are fully adjusted for all patient, provider, and hospital characteristics listed in Table 1 (except for the substage unless otherwise noted).
[b] Patients with extreme costs (costs within the top 5%) were excluded.
[c] The sample was restricted to those diagnosed in 2004 and onward (for whom these data were available).

assess the reasons that patients and their referring providers select particular surgeons and medical oncologists. Some patients receiving 2-hospital care may purposefully seek out specific providers on the basis of reputation, compatibility, or other personal preferences without respect to where the providers practice; these patients are likely to be more active and capable of bridging deficits in coordination across health care systems. To the extent that these patients also have better health outcomes, this may bias our mortality findings toward the null. Although we used propensity score methods to produce patient groups resembling each other on observed covariates, there may still be differences due to unmeasured characteristics. Sixth, our volume measures are based solely on Medicare data; however, volume measures constructed with Medicare data are highly correlated with those constructed from all-payer data.[35] Finally, this study focuses on patients in fee-for-service Medicare and may not be generalizable to younger patients or those in preferred provider organizations, in health maintenance organizations, or with other types of insurance.

Notwithstanding these limitations, the current work suggests the potential that integrated delivery systems may have in reducing cancer costs while underscoring the challenges of doing so. Although many current health care delivery reforms, including accountable care organizations, patient-centered medical homes, and bundled payments, seek to reduce fragmentation, they do not lock patients into receiving care through a single hospital or health system. Efforts to create continuity in complex care may be hampered by the large proportion of patients who receive treatment delivered by providers from more than 1 hospital or system. At the same time, our findings suggest that costs are lower among patients who receive care from a single hospital, and this reinforces the potential financial benefits of delivery models that reduce fragmentation in complex cancer care.

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The authors made no disclosure.

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