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Variation in Primary Site Resection Practices for Advanced Colon Cancer: A Study Using the National Cancer Data Base

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Abstract

Introduction—Treatment of metastatic colon cancer may be driven as much by practice patterns as by features of disease. To optimize management, there is a need to better understand what is determining primary site resection use.

Methods—We evaluated all patients with Stage IV cancers in the National Cancer Data Base between 2002 and 2012 (50,791 patients, 1,230 hospitals). We first identified patient characteristics associated with primary tumor resection. Then, we assessed nationwide variation in hospital resection rates.

Results—Overall, 27,387 (53.9%) patients underwent primary site resection. Factors associated with resection included younger age, having <2 major comorbidities and white race ($P < 0.001$). Nationwide, hospital adjusted primary tumor resection rates ranged from 26.0% to 87.8% with broad differences across geographical areas and hospital accreditation types.

Conclusions—There is statistically significant variation in hospital rates of primary site resection. This demonstrates inconsistent adherence to guidelines in the presence of conflicting evidence regarding resection benefit.

Synopsis

Conflicting evidence to direct surgical decision-making in metastatic colon cancer result in widely varying treatment patterns. We find that the decision to undergo resection of the primary tumor site is influenced not only by patient-specific clinical factors, but also by hospital type and geography.

Keywords

Colon neoplasms; colon surgery; neoplasm metastasis; hospitals; clinical decision-making

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Introduction

Of the 137,000 new cases of colon cancer diagnosed per year in the United States, approximately 20% present with metastatic disease.(1) Compared to other stages of this disease, these patients have substantially worse long-term survival and fewer well-established practice guidelines to direct treatment choices. Historically, primary site resection was common in the setting of metastatic disease, with 74.5% of cases undergoing primary tumor resection in 1988.(2) However, with the use of newer systemic therapies, primary site resection can often be avoided.(3)

Despite these more recent developments, more than two-thirds of patients with metastatic disease continue to undergo primary site resection.(4) Primary site resection in metastatic colon cancers is morbid and its oncologic benefit remains an area of significant controversy, but can be lifesaving in cases of bleeding, perforation or obstruction.(5, 6) The extent to which hospitals' primary site resection rates reflect patient disease characteristics or their culture and habits is also unclear. Other treatment patterns such as chemotherapy, radiation and metastectomy for metastatic colon cancer are highly variable across the country and largely influenced by hospital practices rather than patient disease.(7) Similarly, the same trends may apply specifically to primary site resection in addition to patient and tumor-specific factors such as bleeding or obstruction. The current national landscape of primary site resection practices has not been well described.

In the present study, we evaluated patient and hospital characteristics associated with primary site resection in advanced colon cancers. We hypothesized that patients who undergo primary site resection would have more favorable comorbidity profiles and socio-demographic characteristics. We also hypothesized that regional and hospital-level variation in resection practices would be present but have a weaker influence than patient disease factors.

Material and methods

Data Source and Study Population

The National Cancer Data Base (NCDB) Participant User File (PUF) is a joint project of the American College of Surgeons Commission on Cancer (CoC) and the American Cancer Society. Data represent nearly 70% of all newly diagnosed patients with cancer from greater than 1,500 CoC-accredited hospitals in the United States. Data are collected using standardized coding schemata and have been described previously.(8, 9) The NCDB records both clinical and pathologic stage. We sought to identify patients who were known to be Stage IV prior to any surgical intervention, and thus we chose to use clinical stage for our cohort selection. All patients 18 years were identified with a clinical diagnosis of Stage IV cancer of the colon, rectosigmoid, and rectum from 1998 to 2011 using the *International Classification of Diseases for Oncology 3^d Edition* code for adenocarcinoma (8140) and primary site codes for the colon (C180; C182–189). Excluded patients included those without ultimate adenocarcinoma histology, those with more than one primary malignancy, patients with unknown primary tumor sites, and those who did not have complete treatment status information, follow-up or metastatic disease assessment (eAppendix Figure 1). We

also excluded patients from very low volume hospitals (<10 patients/hospital) from our analysis, as we felt that these hospitals did not have sufficient data for reliable hospital-level analyses.

Statistical Analysis

We first identified clinical and demographic characteristics associated with primary tumor resection. Initially tested covariates included age, sex, race, comorbidities as defined by the Charlson-Deyo comorbidity index (10), patient distance to treating hospital, details regarding median income, high school diploma status, rurality and urban influence, primary tumor site, and whether the patient underwent distant site surgery, any (neoadjuvant or adjuvant) radiation therapy or any chemotherapy. Hospital factors included geographic region of facility as well as facility type (Community vs. Academic/Research vs. Other). We also included quartile of hospital volume, our closest available proxy to hospital size, as a covariate in our analyses. First, we compared characteristics of patients using χ^2 tests for categorical variables and Student's *t*-tests for continuous variables. Then, we performed multiple bivariate regressions using primary site resection as a dependent variable and each of the above covariates as independent variables. Each independent variable that was a significant predictor of primary site resection with $P < 0.1$ was retained in a multivariable model. All factors except for sex were significant predictors and were retained in the model. Our multivariable logistic regression model was created using robust standard errors, to account for hospital-level clustering.

There are several variables tracked by the NCDB, which warrant further description. A brief explanation of these follows and more details may be found on the NCDB data dictionary website.(11) Median household income for the year 2000 and the percentage of people in a given zip code without a high school diploma were both estimated matching patient ZIP codes against 2000 U.S. Census Bureau data. Similar later data regarding median household income and percent with no high school diploma for 2008–2012 were tracked using American Community Survey data for 2008–2012 from the U.S. Census Bureau. Rurality and urban influence are tracked by matching the state/county Federal Information Processing Standard (FIPS) code for a patient against 2013 files from the U.S. Department of Agriculture (USDA) Economic Research Service. Geographic hospital location was based on U.S. Census Division of Reporting facility data. Facility type was based on classification of American College of Surgeons Commission on Cancer Accreditation programs.

Following initial regression analyses, patient-level data was collapsed to the hospital level and reliability adjusted outcomes were then calculated. Reliability adjustment is useful to account for hospitals with small numbers of cases whose crude rates of resection may be skewed due to statistical “noise.”(12–14) Facilities were then ranked by risk- and reliability-adjusted probability of resection and divided into quintiles of probability of resection, with the first quintile including hospitals with the least likely probability of performing primary site resection and the fifth quintile including those hospitals with the highest average probability of performing primary site resections. All statistical analyses were conducted using Stata version 13 (StataCorp LP, College Station, TX). All tests are 2-sided with significance set at a *P* value of less than 0.05.

Results

Patient Characteristics and Comorbidities

There were 50,791 patients from 1,230 hospitals eligible for analysis, of whom 27,387 patients (53.9%) underwent primary site resection. As outlined in Table 1, patients undergoing primary site resection were younger and more likely to be white. There was a similar distribution of patient sex between groups. Patients undergoing primary site resection were less likely to have Charlson-Deyo comorbidity index ≥ 2 and slightly more likely to have an index of zero or one.

Treatment Characteristics

Patients who underwent primary tumor site resection were more likely to receive either neoadjuvant or adjuvant chemotherapy and less likely to receive either neoadjuvant or adjuvant radiation therapy. Patients undergoing primary site resection were also far more likely to undergo distant site resection.

Socio-demographic Characteristics

Patients undergoing primary site resection were more likely to live in communities with higher high school graduation rates and slightly higher median household income on average than those not undergoing primary site resection. Median distance to treating facility was statistically greater (8.3 vs. 7.2 miles; $P < 0.001$) for those undergoing primary site resection.

Univariate and Multivariable Analyses

Results of univariate and multivariable analyses are displayed in Table 2. Controlling for other patient and facility factors, significant patient-level factors associated with not undergoing resection included age 61–80 (OR:0.84; 95% CI: 0.76 – 0.93; $P = 0.001$) or > 80 (OR: 0.70; 95% CI: 0.63 – 0.79; $P < 0.001$) black race (OR:0.85; 95% CI: 0.80–0.90; $P < 0.001$), receipt of any radiation (OR:0.52; 95% CI: 0.47–0.57; $P < 0.001$), and Charlson-Deyo comorbidity score ≥ 2 (OR:0.84; 95% CI: 0.78–0.91; $P < 0.001$). Associations were not statistically significant for high school graduation rates, rural or urban influence, median household income and hospital volume in the multivariable analysis.

Following calculation of risk- and reliability-adjusted hospital-level resection rates, quintiles of hospital resection probability were created with the first quintile representing hospitals with the least likely probability of performing primary site resection and the fifth quintile representing the highest probability, and this is portrayed in Figure 1. The mean for each quintile ranged from 42.7% (95% CI: 35.0% – 50.4%) to 64.4% (95% CI: 57.2% – 71.6%). Significant hospital-level variation in use of primary site resection was present, with adjusted rates at the hospital level ranging from 26.0% (95% CI: 18.5% – 35.2%) to 87.8% (95% CI: 83.0% – 91.4%) for individual hospitals.

Variation in patient odds of resection by facility type, after controlling for patient factors and geography, is shown in Figure 2. Compared to patients at academic/research facilities patients at community or comprehensive community cancer programs were statistically significantly more likely to undergo primary site resection (OR: 1.50; 95% CI: 1.42 – 1.57;

P<0.001). Patients at other designated cancer programs were not statistically any more or less likely than those at academic/research facilities to undergo resection (OR: 0.74; 95% CI: 0.40 – 1.36).

Variation in patient odds of resection by facility geographic location, after controlling for patient factors and facility type, is shown in Table 3. Compared to patients in the Atlantic United States, patients in the Northeast were statistically significantly less likely to undergo primary site resection (OR: 0.87; 95% CI: 0.79 – 0.96; P<0.005). Patients in the Great Lakes/Midwest were equally as likely as Atlantic patients to get resection (OR: 1.04; 95% CI: 0.99 – 1.09; P=0.160). Patients in the Mountain/West/Pacific region were more likely to undergo primary site resection (OR 1.20; 95% CI: 1.13 – 1.28; P<0.001). Patients in the South/Southeast were the most likely to undergo primary site resection (OR 1.39; 95% CI: 1.31 – 1.48; P<0.001).

Discussion

We have shown that 1) statistically significant variation exists in hospital-based utilization of primary site resection in advanced colon cancers; 2) drivers of this appear to include facility type and geographic location, with more patients at community hospitals and at hospitals in the South/Southeastern United States undergoing resection. 3) patient predictors of primary site resection include favorable comorbidity status and white race. This study demonstrates broad overall variation in practice patterns in primary site resection for advanced colon cancers.

This large nationally representative cohort provides a picture of recent practice patterns. The variation that we found most likely reflects the lack of consistent data regarding benefits of primary site resection in Stage IV patients. Current NCCN guidelines are to avoid primary site resection in asymptomatic patients, unless the goal is for cure. However, this is in contrast to past practices in which resection was nearly always part of first-line therapy. Furthermore, these guidelines are in the presence of mixed data regarding efficacy of primary site resection. Work in other cancers has shown that adherence to guidelines depends largely on the quality of supporting data and the availability of institutional resources.(15) As these advanced colon cancer guidelines are in the presence of mixed data, our finding of correspondingly mixed adherence is consistent with this pattern. But this variation is perhaps not clinically warranted.

Our results show substantial variation in practice patterns that is not supported in one clear direction by the current body of literature. One previous similar study of factors associated with resection found that at the patient level, gender, geographic region, insurance status, tumor location, grade and CEA were independent predictors of tumor resection.(16) This study used the Surveillance, Epidemiology and End Results (SEER) Database, which captures approximately 28% of all cancer cases in the U.S. The outcome in their study should be reliable because of the fairly granular data that SEER provides over a large number of years. Our study used the NCDB, which captures over 70% of incident cancer cases in the U.S., a broader nationally representative sample, and our methodology accounts for an array of patient, hospital and regional covariates that are captured in the NCDB,

allowing for the control of many potential confounders. Our findings were similar to the aforementioned study with regard to geographic variation, but we did not find differences based on gender. Our study also shows variation based on facility type, with more patients at community hospitals undergoing resection.

There are many possible explanations for our findings, specifically regarding variation in practice by region and facility type. First, the findings could be reflective of patient access to surgical resection. It does appear that patients undergoing resection traveled farther, and perhaps only patients with the means to seek out complex surgical care at tertiary treatment centers could have done this. Second, we found that patients at community cancer centers were more likely to undergo primary site resection. This might speak to differences in operative management patterns but should not be limited to patient factors, as many were adjusted for in our models. Perhaps patients treated at academic centers did not present for appropriate follow-up or lacked the resources to absorb the personal financial burden of complex cancer surgery, as previous work has shown that cancer patients may substantially alter their care in order to decrease out-of-pocket expenses.(17) Specifically, in patients with colorectal cancer, patients with higher personal financial burdens were found to have higher rates of complications from surgery, which led to more financial stress, with a potential impact on adherence to treatment recommendations.(18) These are all possibilities which could be assessed at academic and community hospitals using a qualitative or mixed methods approach, to better understand these barriers to resection.

Our study has several limitations. First, this is an observational study using registry-based data. Inherent in this is a lack of granularity as to factors that may guide decisions beyond those that were measured in our data. It is not possible to know if these findings represent overuse of resection in asymptomatic patients, or appropriate use in symptomatic patients (e.g. obstructing or bleeding lesions). However, the large cohort provides a broad and representative view of overarching trends that should be reliable. Given that over 27,000 patients (53.9% of all patients with metastatic/stage IV disease) in our cohort underwent primary resection, there were certainly many patients that would fall into each of these categories. Additionally, we were able to control for some markers of patient socioeconomic status and rural locations, both of which might be expected to increase symptomatic presentations. Second, this study relies only on data collected from accredited American College of Surgeons Commission on Cancer (CoC) hospitals. While this means that not every hospital in the U.S. is accounted for, over 1,500 accredited cancer care programs report data to the NCDB.(8) Finally, there is the likelihood that certain time-varying covariates existed over the ten years of our cohort. We chose to treat all covariates equally over time. Trends in resection have been previously studied,(2) and grouping our entire cohort together provided the best statistical power to detect drivers of variation.

We have shown that there is substantial variation in practice patterns for primary site resection in a large nationally representative study of patients with advanced colon cancers in the United States. This study highlights the need for better long-term data to guide decision-making. Additionally, it underscores a likely deviation from current practice guidelines that appears to vary by hospital and be driven by geography and facility type.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Hospital-level variation in risk- and reliability-adjusted primary site resection rates is displayed.

Adjusted Odds of Primary Site Resection by Facility Type

Figure 2.

Adjusted odds of primary site resection by facility type. Results are from model controlling for age, sex, race, comorbidities as defined by the Charlson-Deyo comorbidity index(10), patient distance to treating hospital, details regarding median income, high school diploma status, rurality and urban influence, primary tumor site, whether the patient underwent distant site surgery, any radiation therapy (including interaction between rectal tumor site and radiation receipt) or any chemotherapy, facility geographic location, and hospital volume.

Table 1

Characteristics of patients and hospitals in the study are shown, with stratification into those undergoing primary site resection and those not undergoing primary site resection.

	Whole cohort (n=50,791)	Primary site resection (n=27,387)	No primary site resection (n=23,404)	P Value
Age				<0.001
<=40	2,125 (4.2)	1,299 (4.7)	826 (3.5)	
41 – 60	17,264 (34.0)	10,150 (37.1)	7,114 (30.4)	
61 – 80	23,567 (46.4)	12,526 (45.7)	11,041 (47.2)	
>80	7,835 (15.4)	3,412 (12.5)	4,423 (18.9)	
Sex				0.354
Female	24,983 (49.2)	13,419 (49.0)	11,564 (49.4)	
Male	25,808 (50.8)	13,968 (51.0)	11,840 (50.6)	
Race				<0.001
White	39,549 (77.9)	21,818 (79.7)	17,731 (75.8)	
Black	8,806 (17.3)	4,223 (15.4)	4,583 (19.6)	
Other	2,436 (4.8)	1,346 (4.9)	1,090 (4.7)	
Charlson-Deyo index				<0.001
0	37,517 (73.9)	20,520 (74.9)	16,997 (72.6)	
1	9,748 (19.2)	5,276 (19.3)	4,472 (19.1)	
2	3,526 (6.9)	1,591 (5.8)	1,935 (8.3)	
Received any chemotherapy	30,854 (60.8)	18,283 (66.8)	12,571 (53.7)	<0.001
Received any radiation therapy	2,256 (4.4)	935 (3.4)	1,321 (5.6)	<0.001
Distant site resection	6,408 (12.6)	5,701 (20.8)	707 (3.0)	<0.001
Median distance to facility, miles (IQR)	7.8 (15.0)	8.3 (16.4)	7.2 (13.4)	<0.001
% no HS diploma '00 **				<0.001
29% or more	9,795 (19.3)	4,941 (18.0)	4,854 (20.7)	
20% – 28.9%	11,928 (23.5)	6,420 (23.4)	5,508 (23.5)	
14% – 19.9%	11,130 (21.9)	6,086 (22.2)	5,044 (21.6)	
Less than 14%	15,549 (30.6)	8,629 (31.5)	6,920 (29.6)	
Unknown	2,389 (4.7)	1,311 (4.8)	1,078 (4.6)	
% no HS diploma '08-'12 ***				<0.001
21% or more	10,066 (19.8)	5,093 (18.6)	4,973 (21.3)	
13% – 20.9%	13,848 (27.3)	7,511 (27.4)	6,337 (27.1)	
7% – 12.9%	15,279 (30.1)	8,307 (30.3)	6,972 (29.8)	
Less than 7%	10,101 (19.9)	5,695 (20.8)	4,406 (18.8)	
Unknown	1,497 (3.0)	781 (2.9)	716 (3.1)	
Rurality/Urban influence '03 ****				<0.001
Metro	40,401 (79.5)	21,510 (78.5)	18,891 (80.7)	
Urban	7,172 (14.1)	4,110 (15.0)	3,062 (13.1)	
Rural	921 (1.8)	527 (1.9)	394 (1.7)	
Unknown	2,297 (4.5)	1,240 (4.5)	1,057 (4.5)	

	Whole cohort (n=50,791)	Primary site resection (n=27,387)	No primary site resection (n=23,404)	P Value
Rurality/Urban influence '13 ^{****}				<0.001
Metro	40,963 (80.7)	21,790 (79.6)	19,173 (81.9)	
Urban	6,649 (13.1)	3,844 (14.0)	2,805 (12.0)	
Rural	881 (1.7)	512 (1.9)	369 (1.6)	
Unknown	2,298 (4.5)	1,241 (4.5)	1,057 (4.5)	
Median household income '00 ^{**}				<0.001
Less than \$30,000	7,886 (15.5)	4,007 (14.6)	3,879 (16.6)	
\$30,000 – \$34,999	9,127 (18.0)	4,959 (18.1)	4,168 (17.8)	
\$35,000 – \$45,999	13,370 (26.3)	7,123 (26.0)	6,247 (26.7)	
\$46,000 +	18,024 (35.5)	9,991 (36.5)	8,033 (34.3)	
Unknown	2,384 (4.7)	1,307 (4.8)	1,077 (4.6)	
Median household income '08-'12 ^{***}				<0.001
Less than \$38,000	10,547 (20.8)	5,379 (19.6)	5,158 (22.0)	
\$38,000–\$47,999	12,040 (23.7)	6,571 (24.0)	5,469 (23.4)	
\$48,000–\$62,999	12,537 (24.7)	6,740 (24.6)	5,797 (24.8)	
\$63,000+	14,150 (27.9)	7,899 (28.8)	6,251 (26.7)	
Unknown	1,527 (3.0)	798 (2.9)	729 (3.1)	
Geographic Location ^{*****}				<0.001
Atlantic	19,104 (37.6)	9,910 (36.2)	9,194 (39.3)	
Northeast	2,657 (5.2)	1,299 (4.7)	1,358 (5.8)	
Great Lakes/Midwest	13,349 (26.3)	7,186 (26.2)	6,163 (26.3)	
Mountain/West/Pacific	7,513 (14.8)	4,225 (15.4)	3,288 (14.1)	
South/Southeast	8,168 (16.1)	4,767 (17.4)	3,401 (14.5)	
Facility Type ^{*****}				<0.001
Community/Comprehensive Community	34,216 (67.4)	19,160 (70.0)	15,056 (64.3)	
Academic/Research	16,526 (32.5)	8,207 (30.0)	8,319 (35.6)	
Other Cancer Program	49 (0.1)	20 (0.1)	29 (0.1)	
Hospital volume, cases				0.001
≤ 32	12,852 (25.3)	7,116 (26.0)	5,736 (24.5)	
33 – 51	12,604 (24.8)	6,774 (24.7)	5,830 (24.9)	
52 – 80	13,082 (25.8)	7,008 (25.6)	6,074 (26.0)	
>80	12,253 (24.1)	6,489 (23.7)	5,764 (24.6)	

SD=standard deviation; HS=high school;

* Calculated using Pearson's χ^2 test for categorical variables, two-tailed Student's *t* test for continuous variables and a two-sample Wilcoxon rank-sum (Mann-Whitney) test when medians are reported for continuous variables.

** Estimated by matching ZIP code of patient against 2000 US Census data.

*** American Community Survey data for 2008–2012.

**** Estimated by matching state/county Federal Information Processing Standard (FIPS) code of patient against 2013 files from U.S. Department of Agriculture (USDA) Economic Research Service (<http://www.ers.usda.gov/data-products/rural-urban-continuum-codes>).

US Census Division of reporting facility.

Classification by the Commission on Cancer Accreditation program.

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Table 2

Predictors of primary site resection in the whole cohort are displayed. Results represent odds of undergoing primary site resection with 95% confidence intervals in parentheses.

Factors	Univariate Analysis	Multivariable Analysis
Age		
<=40	Reference	Reference
41 – 60	0.91 (0.83 – 1.00)	0.96 (0.86 – 1.06)
61 – 80	0.72 (0.66 – 0.79)	0.84 (0.76 – 0.93)
>80	0.49 (0.44 – 0.54)	0.70 (0.63 – 0.79)
Sex		
Male	Reference	Not retained in model
Female	0.98 (0.95 – 1.02)	
Race		
White	Reference	Reference
Black	0.75 (0.71 – 0.78)	0.85 (0.80 – 0.90)
Other	1.00 (0.92 – 1.09)	1.03 (0.94 – 1.13)
Charlson-Deyo index		
0	Reference	Reference
1	0.98 (0.93 – 1.02)	1.06 (1.01 – 1.11)
2	0.68 (0.64 – 0.73)	0.84 (0.78 – 0.91)
Received any chemotherapy	1.86 (1.79 – 1.93)	1.63 (1.56 – 1.70)
Received any radiation *****	0.59 (0.55 – 0.65)	0.52 (0.47 – 0.57)
Distant site resection	9.21 (8.50 – 9.98)	9.31 (8.56 – 10.13)
Distance to facility	1.00 (1.00 – 1.00)	1.00 (1.00 – 1.00)
% no HS diploma '00 **		
29% or more	Reference	Reference
20% – 28.9%	1.15 (1.09 – 1.21)	1.06 (0.98 – 1.15)
14% – 19.9%	1.19 (1.12 – 1.25)	1.08 (0.97 – 1.19)
Less than 14%	1.23 (1.16 – 1.29)	1.10 (0.98 – 1.23)
% no HS diploma '08-'12 ***		
21% or more	Reference	Reference
13% – 20.9%	1.16 (1.10 – 1.22)	1.08 (1.00 – 1.16)
7% – 12.9%	1.16 (1.11 – 1.22)	1.04 (0.94 – 1.15)
Less than 7%	1.26 (1.19 – 1.33)	1.08 (0.96 – 1.21)
Rurality/Urban influence '03 *****		
Metro	Reference	Reference
Urban	1.18 (1.12 – 1.24)	0.94 (0.82 – 1.08)
Rural	1.17 (1.03 – 1.34)	0.89 (0.67 – 1.19)
Rurality/Urban influence '13 *****		
Metro	Reference	Reference
Urban	1.21 (1.14 – 1.27)	1.19 (1.03 – 1.37)

Factors	Univariate Analysis	Multivariable Analysis
Rural	1.22 (1.07 – 1.40)	1.24 (0.93 – 1.67)
Median household income '00 ***		
Less than \$30,000	Reference	Reference
\$30,000 – \$34,999	1.15 (1.08 – 1.22)	1.08 (1.00 – 1.17)
\$35,000 – \$45,999	1.10 (1.04 – 1.17)	1.06 (0.96 – 1.16)
\$46,000 +	1.20 (1.14 – 1.27)	1.14 (1.01 – 1.28)
Median household income '08-'12 **		
Less than \$38,000	Reference	Reference
\$38,000–\$47,999	1.15 (1.09 – 1.21)	1.01 (0.94 – 1.09)
\$48,000–\$62,999	1.11 (1.06 – 1.17)	0.96 (0.87 – 1.05)
\$63,000+	1.21 (1.15 – 1.27)	0.96 (0.86 – 1.08)
Hospital volume, cases		
<= 32	Reference	Reference
33 – 51	0.94 (0.89 – 0.98)	0.97 (0.92 – 1.03)
52 – 80	0.93 (0.89 – 0.98)	0.99 (0.94 – 1.05)
>80	0.91 (0.86 – 0.95)	1.03 (0.97 – 1.10)

HS=high school;

** Estimated by matching ZIP code of patient against 2000 US Census data.

*** American Community Survey data for 2008–2012.

**** Estimated by matching state/county Federal Information Processing Standard (FIPS) code of patient against 2013 files from U.S. Department of Agriculture (USDA) Economic Research Service (<http://www.ers.usda.gov/data-products/rural-urban-continuum-codes>).

***** Interaction terms, odds ratios should not be interpreted separately.

Table 3

Adjusted odds of primary site resection by geographic location. Results are from model controlling for age, sex, race, comorbidities as defined by the Charlson-Deyo comorbidity index(10), patient distance to treating hospital, details regarding median income, high school diploma status, rurality and urban influence, primary tumor site, whether the patient underwent distant site surgery, any radiation therapy (including interaction between rectal tumor site and radiation receipt) or any chemotherapy, facility type, and hospital volume.

Region *	Adjusted Odds Ratio (95% Confidence Interval)	P
Atlantic	Reference	
Northeast	0.87 (0.79 – 0.96)	<0.005
Great Lakes/Midwest	1.04 (0.99 – 1.09)	0.160
Mountain/West/Pacific	1.20 (1.13 – 1.28)	<0.001
South/Southeast	1.39 (1.31 – 1.48)	<0.001

* Based on US Census Division of reporting facility