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Research Paper

Positive margin rates for colorectal cancer vary significantly by hospital in Michigan: Can we achieve a 0 % positive margin rate?

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ABSTRACT

Background: High quality surgical care for colorectal cancer (CRC) includes obtaining a negative surgical margin. The Michigan Surgical Quality Collaborative (MSQC) is a statewide consortium of hospitals dedicated to quality improvement; a subset of MSQC hospitals abstract quality of care measures for CRC surgery, including positive margin rate. The purpose of this study was to determine whether positive margin rates vary significantly by hospital, and whether positive margin rates should be a target for quality improvement.

Methods: We performed a retrospective cohort study of patients who underwent CRC resection from 2016 to 2020. The primary outcome was the presence of a positive margin. Univariate and multivariable analyses were performed to test the association of positive margins with patient, hospital, and tumor characteristics.

Results: The cohort consisted of 4211 patients from 42 hospitals (85 % colon cancer and 15 % rectal cancer). The crude positive margin rate was 6.15 % (95 % CI 4.6–7.4 %); this ranged from 0 % to 22 % at individual hospitals. In multivariable analysis, factors independently associated with positive margins included male sex, underweight BMI, metastatic cancer, rectal cancer (vs. colon), T4 T-stage, N1c/N2 N-stage, and open surgical approach. After adjusting for these factors, there remained significant variation by hospital, with 8 hospitals being statistically-significant outliers.

Conclusions: Positive margins rates for CRC vary by hospital in Michigan, even after rigorous adjustment for case-mix. Furthermore, several hospitals achieved near-zero positive margin rates, suggesting opportunities for quality improvement through the identification of best practices among CRC surgery centers.

Introduction

Complete surgical resection is the primary curative treatment for colorectal cancer (CRC). The goal of surgery is to resect the tumor in its entirety by achieving adequate proximal, distal, and circumferential margins and to remove the draining lymph node basin in order to ensure that no residual cancer remains [1,2]. Tumor seen at the edge of the specimen on histologic review is considered a positive resection margin; this indicates that tumor may remain in the patient. The presence of a positive margin is a stage-independent marker of poor outcomes [3–6]. Multiple studies demonstrate that positive margins are associated with decreased overall survival and increased local recurrence rates [7–9]. Despite the known implications of positive margins, rates remain high nationally with a reported 11.6 % positive margin rate for colon cancer and 17.2 % for rectal cancer [1,10–13].

While negative margins for CRC resection are clearly important, the reason so many positive margins occur in real-world clinical practice is not well understood. In the Michigan Surgical Quality Collaborative (MSQC), a project to measure quality of care for colorectal cancer began in 2014, and an included measure of surgical quality is the positive

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margin rate. However, patient and tumor factors associated with positive margins must be well-understood, in order to compare risk-adjusted hospital performance.

In this context, we conducted the present study to identify patient, tumor, and hospital factors associated with CRC margin positivity. The unique MSQC registry combines detailed patient and surgical data with CRC-specific quality measures, and was used to compare risk-adjusted positive margin rates among hospitals. We hypothesized that hospitals' positive margin rates would vary, and that decreasing positive margin rates would prove to be an appropriate target for quality improvement efforts.

Materials and methods

Study setting

We conducted a retrospective cohort study of patients who underwent CRC resection and were captured in the Michigan Surgical Quality Collaborative (MSQC) database. The MSQC is a statewide quality improvement organization funded by Blue Cross and Blue Shield of Michigan (BCBSM) [18]. The voluntary program consists of 69 hospitals that represent the majority of the hospitals performing surgery in the state of Michigan [19]. The collaborative consists of academic and community hospitals with a diverse range of attributes, including case volume and bed counts [20]. Participating hospitals receive funding from BCBSM to train and support Surgical Clinical Quality Reviewers (SCQRs), who perform data abstraction at their local hospitals. This abstraction involves review of patient medical records by SCQRs. Data collected by the MSQC consists of detailed patient characteristics, perioperative processes, laboratory results, and 30-day outcomes for patients undergoing surgery at respective sites [20].

This study evaluated CRC resection patients at 42 MSQC hospitals that elected to participate in the MSQC's CRC Project from 2016 to 2020 [1,21,22]. In addition to routine clinical data, cancer-specific data on colorectal cancer operations was used in our analysis. These data were abstracted from surgical pathology reports and included pathologic T/N staging and the presence or absence of a positive margins [21]. Within the MSQC, a sampling algorithm is used to minimize selection bias, and data collection accuracy is audited annually [20].

MSQC data abstraction and quality assurance are performed as previously described [23–25]. Collection and review of MSQC data are institutional review board exempt at participating hospitals. Not all MSQC hospitals volunteered to participate in the CRC project; data was collected from the 42 MSQC hospitals that did participate [1].

Patient cohort

Our cohort included adult patients (18 years and older) with a primary CRC diagnosis and surgical resection between January 1, 2016 and December 31, 2020. Eligible patients were identified using codes from the International Classification of Diseases 9th and 10th Editions (ICD-9, ICD-10), and by Current Procedural Terminology (CPT) codes, respectively (Supplemental Table 1). Patients with tumor and lymph node stage (T/N) graded as TX, NX, or not recorded were excluded.

Outcomes and explanatory variables

The primary outcome was the occurrence of positive margins following primary CRC surgery. Margin positivity was recorded as 'yes' or 'no' based on pathology report review as documented in the MSQC database.

Patient-level factors included demographic, surgical, and tumor-specific variables. Demographic data included patient age, sex, race and ethnicity, and insurance type. For the purposes of de-identification, patients older than 89 years old were recorded as 89 years old. Patient clinical characteristics included body mass index (BMI), diabetes, smoking status, congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), ascites, sleep apnea, hypertension, dialysis use, pre-operative metastatic cancer, functional status, ventilator use, and immunosuppressive medication use. Smoking status was defined as tobacco use (cigarette) within 1 year from the date of surgery. Surgical variables included surgical priority (elective vs. emergency/urgent), year of operation, and surgical approach (open, laparoscopic, or robotic). Tumor-specific variables included the location of cancer (colon or rectum) and pathologic T/N staging.

Hospital-level factors included publicly available data on hospitals' bed size (<300, 300–499, >500), Core-Based Statistical Area (CBSA) type (metropolitan, micropolitan, or rural), and teaching status, and CRC volume. Hospital CRC volume was defined as the number of colorectal cancer resections captured in the MSQC CRC project database over the study period. Participating hospitals were assigned a site ID to maintain anonymity while allowing for case volume analysis.

Statistical analysis

Descriptive statistics were used to characterize the overall positive margin rates and characteristic-specific rates among subgroups. Pearson's chi-square test was used to compare patient-level and hospital-level categorical variables and positive margin rates. *t*-tests was used to compare the positive margin rate and case volume within the study cohort. Hospitals with fewer than 20 cases ($n = 3$) were excluded from our analysis of positive margin rate compared to volume but were included in the remaining analyses.

A multivariable analysis (hierarchical glimmix model, using hospital site as the random effect) was performed to assess the independent association of patient and hospital factors with positive resection margin [17]. Reliability adjustment of positive margin rate at the hospital level was performed using previously described methods to ensure that the outcomes from participating sites with low CRC case volume were not skewed [1]. Caterpillar plots were created using a stepwise logistic regression model with positive surgical margin as the binary outcome including patient and hospital characteristics as the independent variables. Patient and hospital factors that were associated with positive margin in the bivariate analyses ($p < 0.05$) were included in the model. CRC specific metrics were included, regardless of significance on bivariate analysis, due to clinical importance. These included pre-operative metastatic cancer, T/N stage, surgical priority, surgical approach, and colon versus rectal cancer.

Bivariate analysis was performed using R statistics software (R 4.1.0 "Camp Pontanezen" released in 2021 by the R Project for Statistical Computing). The sgplot procedure was used to create caterpillar plots. All hypotheses were 2-tailed and used a *p*-value of <0.05 for the assessment of statistical significance. Multivariable analysis was performed using SAS 9.4 software.

Results

Cohort characteristics

The study cohort consisted of 4211 patients from 42 hospitals. Mean age was 67.6 (SD 13.4) years. 3566 patients (84.7 %) had colon cancer and 645 patients (15.3 %) had rectal cancer. Patient and hospital characteristics are documented in Table 1.

Unadjusted positive margin rates and risk factors

Between 2016 and 2020, the CRC positive margin rate for the entire cohort was 6.15 % (95 % CI 4.6–7.4 %); this ranged from 0 % to 22 % at individual hospitals (Fig. 1). The average positive margin rate among patients undergoing colon cancer resection was 6.0 % (95 % CI 5.2–6.7 %). The average rate for rectal cancer resections was 7.7 % (95 % CI 5.3–9.3 %).

Table 1
Cohort characteristics.

Characteristic	Overall no. of cases (% of cases) (N = 4211)	No. positive margin cases	Positive margin rate (%)	P
Sex				
Male	2120 (50.3)	146	6.9	0.045*
Female	2091 (49.7)	113	5.4	
Age				
20–35	54 (1.3)	4	7.4	0.403
36–50	452 (10.7)	34	7.5	
51–65	1234 (29.3)	78	6.3	
66–80	1650 (39.2)	88	5.3	
81+	821 (19.5)	55	6.7	
Race/ethnicity				
White	3579 (85.0)	226	6.3	0.306
Black/African American	397 (9.4)	24	6.1	
Other	235 (5.6)	4	3.8	
BMI				
<18.5	137 (3.3)	17	12.4	0.005*
18.5–24.9	1167 (27.7)	75	6.4	
25–29.9	1361 (32.4)	89	6.5	
≥30.0	1542 (36.6)	78	5.1	
Insurance type				
Commercial insurance (non-HMO)	1228 (29.2)	72	5.9	0.692
Other insurance	2983 (70.8)	186	6.2	
Diabetes				
No diagnosis	3312 (78.7)	220	6.6	0.023*
Non-insulin	563 (13.3)	28	5.0	
Insulin	336 (8.0)	11	3.3	
Smoking				
No	3521 (83.6)	206	5.9	0.067
Yes	690 (16.4)	53	7.7	
CHF				
No	4163 (98.9)	255	6.1	0.527
Yes	48 (1.1)	4	8.3	
COPD				
No	3838 (91.1)	233	6.1	0.490
Yes	373 (8.9)	23	7.0	
Ascites				
No	4148 (98.5)	243	5.9	<0.001*
Yes	63 (1.5)	16	25.4	
Sleep apnea				
No	2989 (71.0)	195	6.5	0.115
Yes	1222 (29.0)	64	5.2	
Hypertension				
No	1751 (41.6)	130	7.4	0.004*
Yes	2460 (58.4)	129	5.2	
Dialysis use				
No	4177 (99.2)	258	6.2	0.434
Yes	34 (0.8)	1	2.9	
Pre-operative metastatic cancer				
No	3715 (88.2)	172	4.6	<0.001*
Yes	495 (11.8)	87	17.6	
Functional status				
Partially or totally dependent	198 (4.7)	17	8.6	0.145
Independent	4008 (95.3)	242	6.0	
Ventilator use				
No	4205 (99.9)	258	6.1	0.283
Yes	6 (0.1)	1	16.7	
Immunosuppressive medication				
No	4017 (95.4)	243	6.1	0.275
Yes	194 (4.6)	16	8.3	
Bed size				
<300	1366 (32.4)	84	6.2	0.009*
300–499	1549 (36.8)	115	7.4	
500 or more	1296 (30.8)	60	4.6	
CBSA type				
Metro	3731 (88.6)	214	5.7	0.007*
Micro	424 (10.1)	41	9.7	
Rural	56 (1.3)	4	7.1	
Teaching status				
No	3194 (75.9)	215	6.7	0.005*
Yes	1017 (24.1)	44	4.3	
Cancer location				
Colon	3566 (84.7)	212	5.9	0.192
Rectal	645 (15.3)	47	7.3	
Surgical priority				
Emergent/urgent	1007 (23.9)	105	10.4	<0.001*
Elective	3204 (76.1)	154	4.8	
Surgical approach				
Laparoscopic	1371 (32.6)	51	3.7	<0.001*
Open	1839 (43.7)	168	9.1	
Robotic	1001 (23.7)	40	4.0	
T-stage				
T0 or Tis	126 (3.0)	2	1.6	<0.001*
T1 or T2	1162 (27.6)	17	1.5	
T3	2147 (51.0)	88	4.1	
T4	776 (18.4)	152	19.6	
N-stage				
N0	2452 (58.2)	79	3.2	<0.001*
N1 or N1a or N1b	1007 (23.9)	71	7.1	
N1c or N2 or N2a or N2b	752 (17.9)	109	14.5	

Abbreviations: BMI, body mass index; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; CBSA, core-based statistical area.
Note: p values were calculated using Pearson's chi-square test, except for CBSA Type, which used Fisher's exact test.
* Statistically significant.

The unadjusted analysis did not demonstrate a significant relationship between hospital CRC volume and positive margin rates ($p = 0.083$; Fig. 1). Margin positivity was associated with multiple patient (male sex, underweight BMI, no diabetes, ascites, no hypertension), tumor (T-stage, N-stage, and preoperative metastatic cancer), surgical (open approach, urgent/emergency surgery), and hospital (bed size <500, micropolitan/rural, non-teaching) characteristics (Table 1).

Pathologic stage was strongly associated with positive margin risk. For tumor (T) stage, T4 lesions had a positive margin rate of 19.6 % for both colon (18.4 %) and rectal (39.5 %) cancers, which is higher than the combined rate of 3.1 % for T0 (1.5 %, 1.7 %), T1 (0.8 %, 3.1 %), T2 (1.7 %, 1.6 %) and T3 (3.5 %, 8.2 %) colon and rectal lesions, respectively (Fig. 2). A similar trend was noted when comparing lymph node (N) stage against positive margin rate, as N2 colon (15.8 %) and rectal (17.5 %) lesions had a much higher positive margin rate, 15.9 %, compared to rates for lesions graded as N0, 3.2 % (colon 2.7 %, rectal 5.9 %), or N1, 7.2 % (colon 7.2 %, rectal 6.9 %) (Fig. 2).

Multivariable analysis of risk factors for positive margins

Multivariable analysis with hospital site acting as the random effect revealed various factors that were independently associated with positive resection margins (Table 2). These included male sex (aOR 1.4 [95 % CI 1.1–1.9]), underweight BMI (2.1 [1.1–3.9]), metastatic cancer (2.1 [1.5–2.9]), rectal cancer (vs. colon) (aOR 3.0 [1.9–4.5]), T4 T-stage (13.1 [3.0–57.4]), and N1c/N2 N-stage (2.0 [1.4–2.9]). Laparoscopic surgery was independently associated with a lower positive margin risk (aOR 0.7 [0.5–1.0]). In the multivariable analysis, hospital characteristics were not significantly associated with positive margin rate.

Risk-adjusted positive margin rates ranged from 0 % to 31 % across the 42 participating individual hospitals (Fig. 3). We identified eight hospitals that were statistically significant outliers with respect to positive margins. Eight were “positive outliers,” and three were “negative outliers.” Outliers were defined as hospitals with a positive margin rate whose 95 % confidence interval did not include the average rate (6.15

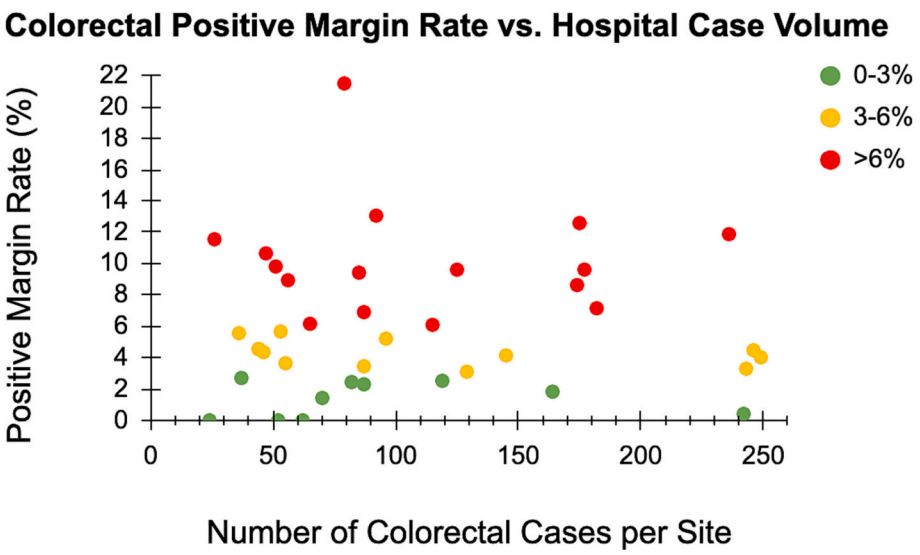

Fig. 1. Unadjusted positive margin rate by hospital case volume.

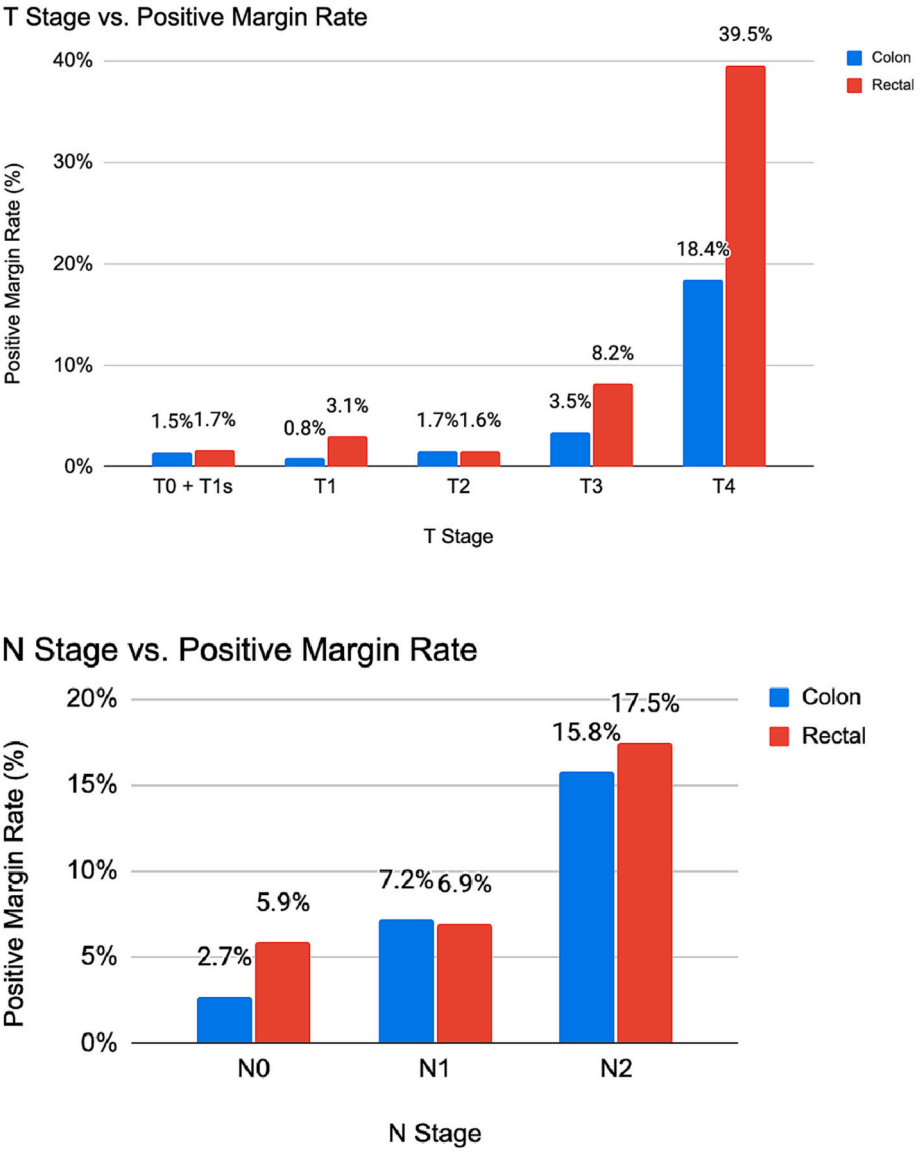

Fig. 2. Unadjusted positive margin rates by pathologic T-stage and N-stage.

Table 2
Multivariate logistic regression for clinical and demographic characteristics associated with positive margins.

Characteristic		Positive-margin adjusted odds ratio	95 % confidence limits		P value
Patient					
Sex	Male (ref: female)	1.40	1.05	1.87	0.025*
BMI	Underweight (ref: normal)	2.07	1.09	3.92	0.027*
	Overweight (ref: normal)	1.15	0.80	1.64	0.449
	Obesity (ref: normal)	1.08	0.75	1.57	0.675
Comorbidities	Diabetes	1.33	0.88	2.01	0.166
	Smoker	1.05	0.72	1.52	0.806
	Hypertension	0.84	0.62	1.13	0.246
	Ascites	2.11	0.98	4.55	0.057
Hospital					
Hospital bed size	Bed size (300–499 beds vs. <300 beds)	1.16	0.62	2.16	0.634
	Bed size (500+ beds vs. <300 beds)	1.32	0.53	3.29	0.544
Hospital location	CBSA (metropolitan vs. micropolitan/ rural)	0.71	0.33	1.53	0.372
Teaching hospital	Teaching Hospital (ref: non-teaching hospital)	0.41	0.15	1.16	0.090
Clinical					
Colon v. rectal cancer	Rectal location (ref: colon)	2.96	1.94	4.50	<0.001*
Elective v. urgent/ emergency	Emergency/ Urgent Priority (ref: elective)	1.11	0.79	1.56	0.545
Surgical approach	Laparoscopic Approach (ref: open)	0.66	0.45	0.97	0.033
	Robotic Approach (ref: open)	0.71	0.45	1.13	0.144
Cancer stage	Pre-operative Metastatic Cancer (ref: no metastasis)	2.06	1.47	2.91	<0.001*
	T1 or T2 (ref: T0 or Tis)	1.15	0.25	5.21	0.857
	T3 (ref: T0 or Tis)	2.62	0.61	11.29	0.195
	T4 (ref: T0 or Tis)	13.11	3.00	57.41	<0.001*
	N1 or N1a or N1b (ref: N0)	1.32	0.91	1.91	0.139
	N1c or N2 (ref: N0)	2.03	1.41	2.91	<0.001*

Abbreviations: BMI, body mass index; CBSA, core-based statistical area.
* Statistically significant.

%). Positive outliers demonstrated a 95 % confidence interval entirely below the average rate, while negative outliers possessed a confidence interval entirely above the average rate.

Discussion

The technical goal of curative-intent CRC surgery is complete removal of the cancer with negative margins. This study identifies a spectrum of success, with some hospitals achieving a near 0 % positive margin rate in CRC resection while other hospitals having adjusted positive margin rates >30 %. Patient-level factors, in particular higher stage tumors, were associated with positive margins. The hospital

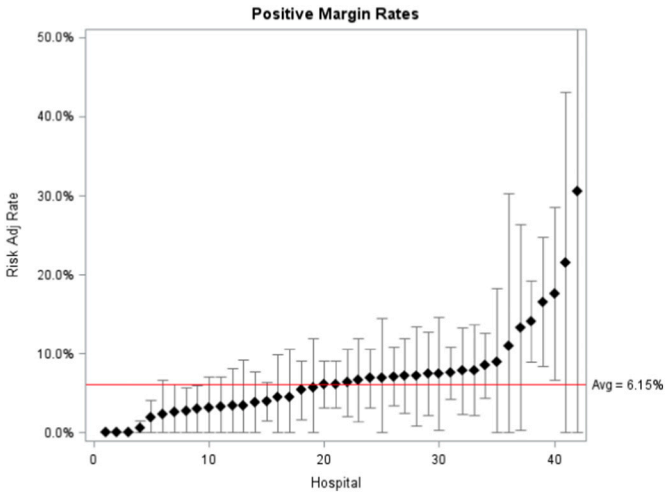

Fig. 3. Risk-adjusted positive margin rate by hospital.

characteristics that we assessed were not significantly associated with positive margin rate. Still, the variation in rates that we identify highlights hospitals with notably low positive margin rates. This is a group of hospitals whose success can provide a foundation for further investigation and potential to fuel quality improvement initiatives that might decrease positive margin rates across the state.

Published national rates of positive margins for both colon and rectal cancer are higher than the rates shown in this study. A study by Rickles et al. analyzed rectal cancer data on a patient population from the U.S. National Cancer Database from 2010 to 2011, concluding that 17.2 % had positive circumferential resection margins [11]. For colon cases, Healy et al. found an overall positive margin rate of 11.6 % in a cohort of 170,022 patients from 2010 to 2015 [12]. The present study, using a prospective statewide registry with newer data than that available from tumor registries, showed a positive margin rate of 6.15 % overall. The lower rates in Michigan may be related to the more recent study period, or to the fact that MSQC has been providing audit and feedback on CRC surgery quality (including positive margin rates) since 2014 as a part of the CRC Project. When considering surgical volumes, some studies show that rectal cancer positive margin rates were not associated with hospital volume [2,11], while others showed an association [12]. We did not identify a significant association between CRC volume and margin positivity. Within our Michigan collaborative group, the idea of regionalizing subspecialty care is unpopular. Rather, our approach is to focus on improving care at every hospital. Within the MSQC, we do have CRC specialists, who work with hospitals and surgeons in the state to improve care. This is not done through policy or payment measures but rather it occurs within the collaborative community.

Unsurprisingly, our work demonstrates that high positive margin rates are most strongly associated with advanced cancer stage. This association has historic precedent for both colon and rectal cancer and follows logic given that advanced cancers are more difficult to remove and operations may be performed with palliative intent [12,26]. Of note, some high-volume hospitals have very low positive margin rates, suggesting that referral centers may overcome higher case complexity with changes in practice. For example, high-quality imaging (e.g., MRI for rectal cancer), utilization of neoadjuvant therapy prior to surgery, variations in patient selection, and avoiding emergency resections in favor of diverting colostomy may contribute to this finding. In addition, these hospitals may be able to preoperatively identify patients with more complex (e.g. T4) tumors that require resection of adjacent organs while having access to other surgical subspecialists to assist with these extended resections. These hypothesized variations in practice can be further studied, understood, and shared in the setting of a quality collaborative. A clear next step is a qualitative examination of high-

performing sites to identify clinical practices in those hospitals with near-zero percent positive margin rates.

Though the validated MSQC registry and its prospective, standardized approach to data collection are definite strengths of our study, the work also has several limitations. First, this study is limited to the state of Michigan and may not be broadly representative of other populations throughout the United States and other countries. Additionally, because we do not have data on surgeon characteristics, we are unable to evaluate surgeon-specific variables, though our previous work suggests that surgeon-specific reporting has significant statistical limitations [27]. Third, our assessment of surgical volume is limited to the number of CRC cases available in our dataset. Given the sampling strategy, this may skew results particularly at low volume centers where CRC cases may be oversampled to near 100 %. However, this approach should underestimate the relationship. Finally, we were not able to capture the location of positive margin (e.g., proximal, distal, or circumferential) in this dataset. This will be an important component of future work as we further explore opportunities to mitigate positive margin rates in Michigan.

Based on our findings, there are several next steps for the state of Michigan specifically. First, this data has been shared across the MSQC collaborative and experts have begun the process of studying best practices through qualitative research. There is an active colorectal surgery video-coaching program within the MSQC that will include content on colorectal cancer surgical technique. Other interventions to decrease positive margin rates in the MSQC might include: root cause analysis for all positive margin cases within each hospital; education about diverting colostomy as an alternative to resection for emergency rectosigmoid operations; and treatment pathways for colorectal cancer patients with tumors involving multiple organs/structures. These and other interventions may improve positive margin rates over time.

In conclusion, this study shows significant variation between hospitals in risk-adjusted positive margin rates for CRC, suggesting opportunities for quality improvement. The existing learning health system of the MSQC is well suited to drive change. Our goal is to pursue an aspirational goal of 0 % positive margin rate in Michigan for colorectal cancer surgery.

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Ethics approval

This study was “exempt” from formal IRB approval, because it utilized a deidentified data set from the MSQC registry (which is also IRB exempt).

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CRediT authorship contribution statement

Lauren Bertoy: Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Calista M. Harbaugh:** Investigation, Validation, Writing – review & editing. **M. Andrew Millis:** Supervision, Writing – original draft, Writing – review & editing. **Lucy Zhuo:** Conceptualization, Supervision, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Nicholas Gutsche:** Conceptualization, Data curation, Formal analysis, Investigation, Writing – review & editing. **Graham Beck:** Conceptualization, Data curation, Formal analysis, Investigation, Writing – review & editing. **Kate Panzer:** Conceptualization, Data curation, Formal analysis, Investigation, Writing – review & editing. **Ryan Howard:** Conceptualization, Investigation, Writing – review & editing. **Wenjing Weng:** Methodology, Data curation, Formal analysis, Writing – review & editing. **Kushal Singh:** Data curation, Formal analysis, Writing – review & editing. **Michael Englesbe:** Conceptualization, Supervision, Writing – original draft, Writing – review & editing. **Samantha Hendren:** Conceptualization, Supervision, Methodology, Data curation, Investigation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

None.

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