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With widespread adoption of MIS colectomy for colon cancer, does hospital type matter?

K. Freischlag[2] · M. Adam[1] · M. Turner[1] · J. Watson[1] · B. Ezekian[1] · P. M. Schroder[1] · C. Mantyh[1] · J. Migaly[1]

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Abstract

Background Recent studies have shown that hospital type impacts patient outcomes, but no studies have examined hospital differences in outcomes for patients undergoing minimally invasive surgery (MIS) for segmental colectomies.

Methods The 2010–2014 National Cancer Data Base was queried for patients undergoing segmental colectomy for non-metastatic colon adenocarcinoma. Descriptive statistics characterized MIS utilization by hospital type. Multivariable models were used to examine the effect of hospital type on outcomes after MIS. Survival probability was plotted using the Kaplan–Meier method.

Results 80,922 patients underwent MIS segmental colectomy for colon cancer from 2010 to 2014. From 2010 to 2014, the number of MIS segmental colectomies increased by 157% at academic hospitals, 151% at comprehensive hospitals, and 153% at community hospitals. Compared to academic hospitals, community and comprehensive hospitals had greater adjusted odds of positive margins (Community OR 1.525, 95% Confidence Interval 1.233–1.885; Comprehensive OR 1.216, 95% CI 1.041–1.42), incomplete number of lymph nodes analyzed (< 12 LNs) from surgery (Community OR 2.15, 95% CI 1.98–2.32; Comprehensive OR 1.42, 95% CI 1.34–1.51), and greater 30-day mortality (Community OR 1.43, 95% CI 1.14–1.78; Comprehensive OR 1.36, 95% CI 1.17–1.59). Patient survival probability was higher at academic hospitals at 5 years (Academic 69% vs. Comprehensive 66% vs. Community 63%, $p < 0.001$). Community hospitals and comprehensive hospitals had significantly higher risk of adjusted long-term mortality (Community HR 1.28; 95% CI 1.19–1.37; $p < 0.001$; Comprehensive HR 1.14; 95% CI 1.09–1.20; $p < 0.001$).

Conclusions Despite widespread use of laparoscopic oncologic surgery, short- and long-term outcomes from MIS for segmental colectomy are superior at academic hospitals. This difference may be due to superior perioperative oncologic technique and surgical outcomes at academic hospitals. Our data provide important information for patients, referring physicians, and surgeons about the significance of hospital type in management of colon cancer.

Keywords Hospital type · Colorectal · Malignancy · Resection · Outcomes

Minimally invasive surgery (MIS) is associated with significantly improved short-term outcomes with reduced length of hospitalization, risks for surgical site infections, estimated blood loss, pain scores and narcotic use, and time to return of bowel function [1–18]. While most major studies demonstrating the superior short-term and equivalent oncological outcomes of MIS were completed only at large academic hospitals, most patients receive their care at non-academic hospitals [5–9, 19]. Despite an overall increase in the laparoscopic colectomy technique for cancer, utilization has been variable between community, comprehensive community, and academic hospitals [20–22]. Subsequently, recent trends in utilization and outcomes of MIS overall and by hospital type in segmental colectomy are unclear.

Our study examines the most recent trends in MIS utilization for segmental colectomy overall and by hospital types. While studies have established a positive correlation between hospital volume, outcomes, and mortality [23–28],

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✉ K. Freischlag
kyle.freischlag@dm.duke.edu

[1] Duke University Medical Center, Surgery, Durham, NC, USA

[2] Duke University School of Medicine, Durham, NC, USA

few studies have examined the impact of hospital type on outcomes from MIS segmental colectomy. Further, MIS segmental colectomy is a widely performed procedure, making comparisons across all hospital types appropriate. Previous colorectal studies have focused on the impact of hospital type in rectal cancer but not colon cancer, a notably different disease process. The prior work on rectal resections is likely not translatable to segmental colectomy because rectal cancer surgery represents a comparatively significant increase in technical difficulty, management complexity, and oncologic outcomes over colon resection [29]. Therefore, we decided to examine outcomes following MIS colon resection for cancer by hospital type. Differences in outcomes based on treatment location may be informative for patients, referring physicians, and surgeons. This study evaluates the impact of hospital type on survival as well as perioperative and oncological outcomes following MIS colectomy.

Methods

Data source

Jointly sponsored by the American College of Surgeons and the American Cancer Society, the National Cancer Database (NCDB) is a clinical oncology database that gathers data from more than 1500 Commission on Cancer (CoC)-accredited hospitals. The database captures an estimated 75% of all new colon cancer diagnoses from the United States and Puerto Rico and contains over 30 million patient records [30, 31].

Study outcomes

The primary endpoint of our study was overall survival. Secondary endpoints included short-term perioperative and oncologic outcomes, such as margin positivity (defined as either distal or circumferential margin), number of lymph nodes (LNs) analyzed, length of stay (LOS), 30-day postoperative readmission, 30-day postoperative mortality, and 90-day postoperative mortality.

Study design

Our institution's Institutional Review Board approved this retrospective analysis from the NCDB. Using the 3rd Edition of International Classification of Diseases for Oncology histology codes (8140, 8141, 8143, 8144, 8145, 8147, 8150, 8210, 8211, 8220, 8221, 8260, 8261, 8262, 8263, 8310, 8320, 8323, 8380, 8401, 8410, 8440, 8460, 8470, 8490, 8500, 8503, 8510), all adult patients in the NCDB with non-metastatic colon adenocarcinoma from 2010 to 2014 undergoing minimally invasive segmental colectomy were identified. Patients with missing surgical approach or hospital type data, history of any other malignancy, or those with clinically apparent metastatic disease were excluded.

The majority of all variables were extracted from the database and a list of data definitions is provided by the NCDB [32]. The number of lymph nodes analyzed is provided by the NCD database. Analysis of lymph nodes was considered incomplete if analysis of less than the nationally recommended number of 12 lymph nodes was reported [33, 34]. Annual income and education status are determined by the National Cancer Data Base by linking a patient's zip code to 2000 US Census data.

The Charlson–Deyo Index predicts 1-year mortality for patients with comorbid conditions and disease severity. Each comorbid condition is assigned a score of 1, 2, 3, or 6 depending on the mortality risk of that condition. The scores are then summed to predict total mortality. We compared scores of 0, 1, and greater than 2.

Hospital type was delineated using the NCDB definitions of academic hospitals, comprehensive cancers hospitals, and community cancer hospitals. Academic hospitals are defined as facilities associated with university medical schools or designated as National Cancer Institute Comprehensive Cancer Care Programs. Comprehensive cancer hospitals as those that treat 650 or more cancer cases annually. Community cancers hospitals as facilities which diagnose and/or treat 100–649 cancer cases annually [35].

Statistical analysis

Patients were stratified based on whether they received surgery at an academic center, community comprehensive center, or community hospital. Baseline characteristics and unadjusted outcomes were compared using the Kruskal–Wallis test for continuous variables and Pearson χ^2 test for categorical variables. For short-term outcomes, multivariable linear and logistic regression models were generated adjusting for hospital type, patient age, sex, race, insurance status, Charlson–Deyo comorbidity index, pathologic stage, and tumor grade. For long-term survival, a multivariable Cox proportional hazard model was generated adjusting for hospital type, patient age, sex, race, insurance status, comorbidities, pathologic stage, tumor grade, and receipt of adjuvant chemotherapy. Unadjusted survival probability was plotted using the Kaplan–Meier method and the log-rank test.

A subset analysis of overall survival and short-term outcomes was performed limited to hospitals in the highest volume tertile (median volume 75 cases/year, IQR 61–105). Survival probability in high-volume hospitals by hospital type was compared using the Kaplan–Meier method. Surgical margins, incomplete lymph nodes analysis, 30-day

readmission, 90-day mortality, and length of stay were compared by hospital type in this subset.

A p-value of less than 0.05 was deemed statistically significant. Statistical analysis was performed using SAS 9.4 (Cary, NC, USA).

Results

A total of 80,922 patients who underwent MIS for segmental colectomy for Stage I-III colon adenocarcinoma from 2010 to 2014 at academic hospitals, comprehensive community hospitals, or community hospitals were included for analysis. Overall, 27.5% (22,230) of cases were performed at academic, 61.4% (49,703) at comprehensive community, and 11.1% (8989) at community hospitals. From 2010 to 2014, the number of MIS segmental colectomies increased by 157% (3397–5347) for academic hospitals, 151% (7719–11,658) for comprehensive hospitals, and 153% (12,497–19,111) for community hospitals. Percentage of MIS segmental colectomies vs. open colectomies for colon cancer increased across all hospital types from 2010 to 2014 (Academic 43.6–63.0%, Comprehensive 40.3–58.9%, Community 30.6–46.8%; Fig. 1).

Academic hospitals treated a higher percentage of minority patients than community hospitals or comprehensive community hospitals (Black: Academic 13.84% vs. Comprehensive 10.24% vs. Community 8.8%; Other: Academic 6.88% vs. Comprehensive 4.48% vs. Community 4.62%, $p < 0.0001$). Academic hospitals also treated a higher percentage of uninsured patients (Academic 2.45% vs. Comprehensive 1.92% vs. Community 2.17%, $p < 0.0001$). Additionally, academic hospitals treated a significantly higher percentage of patients with more comorbidities (Academic 9.33% vs. Comprehensive 9.25% vs. Community 8.67%, $p < 0.0001$) and a higher percentage of patients with high tumor grade (Academic 16.87% vs. Comprehensive 16.76% vs. Community 15.36%, $p < 0.0001$). Baseline characteristics and unadjusted outcomes between hospital types are shown in Table 1.

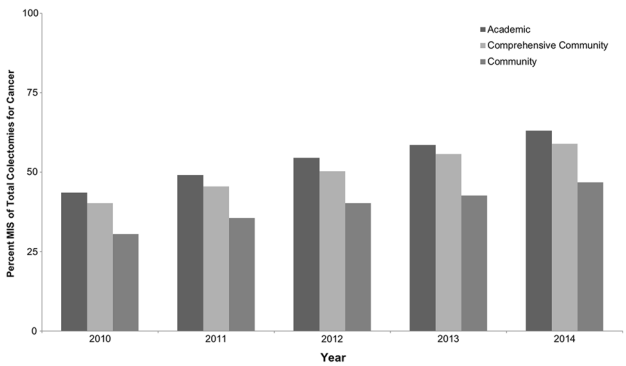


Fig. 1 Percentage of MIS segmental colectomies versus open colectomies for colon cancer across all hospital types from 2010 to 2014

Unadjusted perioperative and oncologic outcomes

Before adjustment, academic hospitals had fewer patients with incomplete tumor resections (Academic 2.43% vs. Comprehensive 2.96% vs. Community 3.97%, $p < 0.0001$). Length of hospital stay was statistically significant but not necessarily clinically consequential (Academic 5.99 days vs. Comprehensive 6.00 days vs. Community 6.18 days, $p < 0.0001$). Both 30-day readmission and rate of complete (≥ 12) LN retrieval and analysis were not different between hospital types. However, academic hospitals had significantly lower 30-day mortality (Academic 1.35% vs. Comprehensive 1.97% vs. Community 2.10%, $p < 0.0001$) and 90-day mortality (Academic 2.53% vs. Comprehensive 3.42% vs. Community 3.66%, $p < 0.0001$).

Adjusted perioperative and oncologic outcomes

After adjustment for patient demographics, comorbidities, and oncologic characteristics, a higher likelihood of margin positivity was associated with treatment at community hospitals compared to academic hospitals (OR 1.525, 95% Confidence Interval 1.233–1.885, $p < 0.0001$) and comprehensive hospitals (OR 1.216, 95% CI 1.041–1.42, $p = 0.0138$; Table 2).

After adjustment, higher odds of incomplete LN retrieval and analysis (< 12 LNs) were associated with treatment at community hospitals (OR 2.145, 95% CI 1.984–2.319, $p < 0.0001$) and comprehensive hospitals (OR 1.424, 95% CI 1.344–1.51, $p < 0.0001$) versus academic hospitals (Table 2).

Treatment at community hospitals (OR 1.428, 95% CI 1.144–1.782, $p = 0.0016$) and treatment at comprehensive community hospitals (OR 1.362, 95% CI 1.167–1.591, $p < 0.0001$) were associated with greater adjusted 30-day mortality compared to academic hospitals for patients undergoing MIS colectomy. Other factors associated with increased 30-day mortality were as follows: age (OR 1.085, 95% CI 1.078–1.093, $p < 0.0001$), female sex (OR 1.443, 95% CI 1.274–1.635, $p < 0.0001$), black race (OR 1.305, 95% CI 1.063–1.603, $p = 0.01$), Charlson–Deyo Score of 1 vs. 0 (OR 1.497, 95% CI 1.298–1.727, 0.006), Charlson–Deyo Score of 2 + vs. 0 (OR 2.547, 95% CI 2.17–2.989, $p < 0.0001$), pathologic stage 2 vs. stage 1 (OR 1.343, 95% CI 1.146–1.574, $p = 0.0003$), pathologic stage 3 vs. stage 1 (OR 1.424, 95% CI 1.207–1.68, $p < 0.0001$), and high tumor grade (OR 1.201, 95% CI 1.033–1.396, $p = 0.02$). Having insurance was associated with lower odds of 30-day mortality (OR 0.531, 95% CI 0.309–0.915, $p = 0.02$) (Table 2).

Table 1 Characteristics of patients who had minimally invasive segmental colectomy for colon cancer by hospital type

	Academic ($N=22,230$)	Comprehensive community ($N=49,703$)	Community ($N=8989$)	All patients ($N=80,922$)	p Value
Patient age (years, median, IQR)	68 (58–78)	70 (60–79)	70 (61–79)	70 (60–79)	< 0.0001
Female gender	11,165 (50.22%)	25,106 (50.51%)	4506 (50.13%)	40,777 (50.39%)	0.73
Race					< 0.0001
Black	3077 (13.84%)	5089 (10.24%)	791 (8.8%)	8957 (11.07%)	
Other	1530 (6.88%)	2228 (4.48%)	415 (4.62%)	4173 (5.16%)	
White	17,623 (79.28%)	42,386 (85.28%)	7783 (86.58%)	67,792 (83.77%)	
Annual household income*					< 0.0001
<$48,000	7623 (34.29%)	18,340 (36.9%)	3864 (42.99%)	29,827 (36.86%)	
>$48,000	14,541 (65.41%)	31,211 (62.8%)	5097 (56.7%)	50,849 (62.84%)	
Higher education*					< 0.0001
No	8839 (39.76%)	19,574 (39.38%)	4027 (44.8%)	32,440 (40.09%)	
Yes	13,334 (59.98%)	30,004 (60.37%)	4936 (54.91%)	48,274 (59.65%)	
Insurance status					< 0.0001
No Insurance	545 (2.45%)	954 (1.92%)	195 (2.17%)	1694 (2.09%)	
Insurance	21,405 (96.29%)	48,344 (97.27%)	8704 (96.83%)	78,453 (96.95%)	
Insurance type					< 0.0001
Private	7997 (35.97%)	16,792 (33.78%)	2680 (29.81%)	27,469 (33.95%)	
Medicaid	1131 (5.09%)	1433 (2.88%)	327 (3.64%)	2891 (3.57%)	
Medicare	12,150 (54.66%)	29,679 (59.71%)	5614 (62.45%)	47,443 (58.63%)	
None	545 (2.45%)	954 (1.92%)	195 (2.17%)	1694 (2.09%)	
Other	127 (0.57%)	440 (0.89%)	83 (0.92%)	650 (0.8%)	
Charlson–Deyo score					< 0.0001
0	15,079 (67.83%)	32,837 (66.07%)	6047 (67.27%)	53,963 (66.69%)	
1	5078 (22.84%)	12,270 (24.69%)	2163 (24.06%)	19,511 (24.11%)	
2+	2073 (9.33%)	4596 (9.25%)	779 (8.67%)	7448 (9.2%)	
Patient location					< 0.0001
Metro/Urban	21,416 (96.34%)	47,619 (95.81%)	8584 (95.49%)	77,619 (95.92%)	
Rural	268 (1.21%)	969 (1.95%)	230 (2.56%)	1467 (1.81%)	
Hospital location					< 0.0001
Midwest	6193 (27.86%)	11,112 (22.36%)	2895 (32.21%)	20,200 (24.96%)	
Northeast	8902 (40.04%)	7289 (14.67%)	1872 (20.83%)	18,063 (22.32%)	
South	4912 (22.1%)	21,494 (43.24%)	2949 (32.81%)	29,355 (36.28%)	
West	2223 (10%)	9808 (19.73%)	1273 (14.16%)	13,304 (16.44%)	
Year of diagnosis					< 0.0001
2010	3397 (15.28%)	7719 (15.53%)	1381 (15.36%)	12,497 (15.44%)	
2011	3928 (17.67%)	9031 (18.17%)	1666 (18.53%)	14,625 (18.07%)	
2012	4458 (20.05%)	10,046 (20.21%)	1879 (20.9%)	16,383 (20.25%)	
2013	5100 (22.94%)	11,249 (22.63%)	1957 (21.77%)	18,306 (22.62%)	
2014	5347 (24.05%)	11,658 (23.46%)	2106 (23.43%)	19,111 (23.62%)	
Tumor size (cm, median, IQR)	3.8 (2.5–5.2)	3.9 (2.5–5.4)	3.9 (2.5–5.3)	3.8 (2.5–5.3)	0.15
Pathologic stage					< 0.0001
1	7655 (34.44%)	16,926 (34.05%)	3072 (34.18%)	27,653 (34.17%)	
2	7412 (33.34%)	16,585 (33.37%)	2964 (32.97%)	26,961 (33.32%)	
3	7163 (32.22%)	16,192 (32.58%)	2953 (32.85%)	26,308 (32.51%)	
High tumor grade					< 0.0001
No	17,430 (78.41%)	39,682 (79.84%)	7258 (80.74%)	64,370 (79.55%)	
Yes	3751 (16.87%)	8328 (16.76%)	1381 (15.36%)	13,460 (16.63%)	
Neoadjuvant chemotherapy					< 0.0001
No	21,700 (97.62%)	48,881 (98.35%)	8802 (97.92%)	79,383 (98.1%)	

Table 1 (continued)

	Academic ($N=22,230$)	Comprehensive community ($N=49,703$)	Community ($N=8989$)	All patients ($N=80,922$)	p Value
Yes	131 (0.59%)	199 (0.4%)	36 (0.4%)	366 (0.45%)	
Neoadjuvant radiotherapy					< 0.0001
No	21,935 (98.67%)	49,197 (98.98%)	8826 (98.19%)	79,958 (98.81%)	
Yes	41 (0.18%)	53 (0.11%)	12 (0.13%)	106 (0.13%)	
Adjuvant chemotherapy					< 0.0001
No	15,744 (70.82%)	35,885 (72.2%)	6458 (71.84%)	58,087 (71.78%)	
Yes	6087 (27.38%)	13,195 (26.55%)	2380 (26.48%)	21,662 (26.77%)	
LN number	19 (14–25)	18 (14–24)	16 (13–22)	18 (14–24)	< 0.0001
LN < 12					0.73
No	20,366 (91.6%)	44,039 (88.6%)	7544 (83.9%)	71,949 (88.9%)	
Yes	1864 (8.4%)	5664 (11.4%)	1445 (16.1%)	8973 (11.1%)	
Surgical margins					< 0.0001
Negative	21,607 (97.2%)	48,101 (96.78%)	8597 (95.64%)	78,305 (96.77%)	
Positive	540 (2.43%)	1470 (2.96%)	357 (3.97%)	2367 (2.93%)	
Mean Length of Stay (SD)	5.99 (5.64)	6.00 (5.34)	6.18 (5.54)	6.02 (5.45)	< 0.0001
30-day readmission					0.33
No	20,869 (93.88%)	47,135 (94.83%)	8448 (93.98%)	76,452 (94.48%)	
Yes	1167 (5.25%)	2450 (4.93%)	492 (5.47%)	4109 (5.08%)	
30-day mortality ($n=60,797$)					< 0.0001
No	16,399 (98.65%)	36,658 (98.03%)	6635 (97.90%)	59,692 (98.18%)	
Yes	225 (1.35%)	738 (1.97%)	142 (2.10%)	1105 (1.82%)	
90-day mortality ($n=60,181$)					< 0.0001
No	16,010 (97.47%)	35,767 (96.58%)	6476 (96.34%)	58,253 (96.80%)	
Yes	416 (2.53%)	1266 (3.42%)	246 (3.66%)	1928 (3.20%)	

Values are presented as percentages of given sample size

IQR Interquartile range, *LN* Lymph node, *SD* standard deviation

*Annual income and education status are determined by the National Cancer Data Base by linking a patient's zip code to 2000 US Census data

Survival analysis

Overall, 5-year patient survival following MIS colectomy was superior at academic hospitals (69%) compared to Comprehensive (66%, $p < 0.001$) or Community (63%, $p < 0.001$) hospitals (Fig. 2). After adjustment using the Cox proportional hazard model, patients who had treatment at community hospitals (hazard ratio [HR] 1.278; 95% CI 1.191–1.372; $p < 0.001$) and comprehensive hospitals (HR 1.139; 95% CI 1.085–1.196; $p < 0.001$) had significantly higher risk of mortality compared to those undergoing resection at academic hospitals (Table 3).

High-volume hospitals

Among patients who had minimally invasive segmental colectomy for colon cancer at a hospital in the highest volume tertile at a by hospital type, 5-year survival probability was increased at academic hospitals vs. comprehensive and community hospitals (76 vs. 73 vs. 58%, $p < 0.01$; Fig. 3). Patients had significantly lower rates of positive margins (2.2 vs. 4.96 vs. 2.57%, $p < 0.0001$), higher rates of adequate lymph node analysis (6.95 vs. 20.66 vs. 9.46%, $p < 0.0001$), and lower 90-day mortality at an academic hospital (1.47 vs. 1.65 vs. 2.12%, $p < 0.0001$; Table 4).

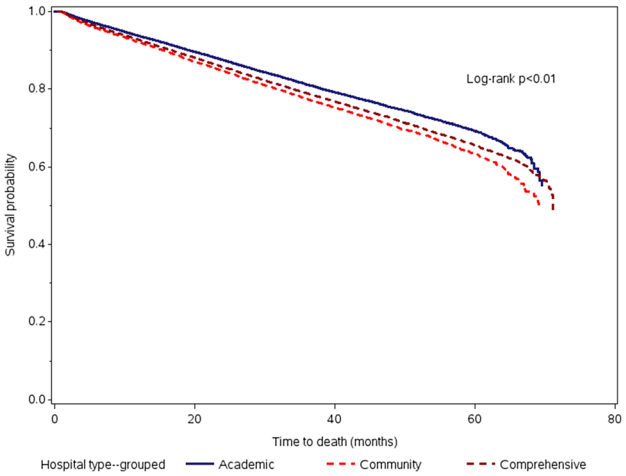
Discussion

This study is the most contemporary national-level analysis examining oncologic and survival outcomes of MIS segmental colectomy for stage I–III colon adenocarcinoma by hospital type. Overall, MIS colectomy has greatly increased across all hospital types since 2010. MIS segmental colectomy performed at an academic hospital was associated with significantly lower rates of positive margins, greater percentage of complete LNs retrieved and analyzed, decreased 30- and 90-day mortality, and greater overall survival compared to MIS surgery performed at a comprehensive hospital or a community hospital. Notable

Table 2 Odds Ratios for clinical outcomes of patients who had minimally invasive segmental colectomy for colon cancer

Effect	OR	95% Wald confidence limits
Odds ratio estimates for positive margins		
Community vs. academic facility	1.525	(1.233–1.885)
Comprehensive vs. academic facility	1.216	(1.041–1.42)
Female vs. male sex	0.984	(0.865–1.12)
Black vs. white race	0.883	(0.709–1.101)
Other vs. white race	1.047	(0.779–1.408)
Insured vs. not insured	1.298	(0.852–1.979)
Charlson–Deyo 1 vs. 0	1.026	(0.88–1.195)
Charlson–Deyo 2 vs. 0	0.996	(0.787–1.262)
T2 vs. T1	0.911	(0.709–1.17)
T3 vs. T1	0.986	(0.822–1.183)
T4 vs. T1	6.281	(5.192–7.597)
Pathologic stage 2 vs. 1	3.881	(2.861–5.265)
Pathologic stage 3 vs. 1	7.922	(5.922–10.598)
High grade vs. low grade	1.68	(1.462–1.93)
Odds ratio estimates for < 12 LNs		
Community vs. academic facility	2.145	(1.984–2.319)
Comprehensive vs. academic facility	1.424	(1.344–1.51)
Age	1.01	(1.008–1.012)
Female vs. male sex	1.28	(1.221–1.341)
Black vs. white race	1.233	(1.147–1.326)
Other vs. white race	1.017	(0.912–1.135)
Insured vs. not insured	1.072	(0.895–1.283)
Charlson–Deyo 1 vs. 0	1.08	(1.023–1.14)
Charlson–Deyo 2 vs. 0	1.205	(1.116–1.301)
Pathologic stage 2 vs. 1	0.426	(0.403–0.451)
Pathologic stage 3 vs. 1	0.444	(0.419–0.47)
High grade vs. low grade	0.884	(0.825–0.946)
Odds ratio estimates for 30-day mortality		
Community vs. academic facility	1.428	(1.144–1.782)
Comprehensive vs. academic facility	1.362	(1.167–1.591)
Age	1.085	(1.078–1.093)
Female vs. male sex	1.443	(1.274–1.635)
Black vs. white race	1.305	(1.063–1.603)
Other vs. white race	0.9	(0.641–1.264)
Insured vs. not insured	0.531	(0.309–0.915)
Charlson–Deyo 1 vs. 0	1.497	(1.298–1.727)
Charlson–Deyo 2 vs. 0	2.547	(2.17–2.989)
Pathologic stage 2 vs. 1	1.343	(1.146–1.574)
Pathologic stage 3 vs. 1	1.424	(1.207–1.68)
High grade vs. low grade	1.201	(1.033–1.396)

differences in patient demographics and tumor characteristics were observed between hospital types, with academic hospitals treating patients with more comorbidities and higher-grade tumors. Despite this, treatment at academic hospitals was associated with improved outcomes and survival.



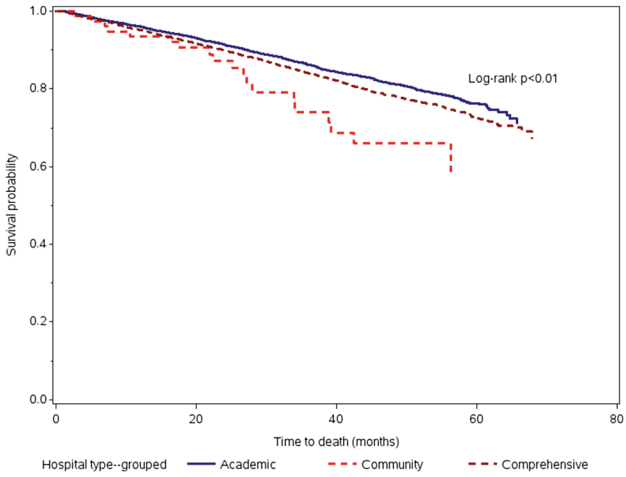
Type	2yr	5yr	p-value
Academic	88	69	
Comprehensive	86	66	<0.0001
Community	85	63	

Fig. 2 Kaplan–Meier Survival Analysis of Minimally Invasive Segmental Colectomies for Colon Cancer by Hospital Type

Table 3 Hazard ratios for overall survival of patients who had minimally invasive segmental colectomy for colon cancer

Parameter	Hazard ratio	95% Hazard ratio confidence limits
Community vs. academic facility	1.278	(1.191–1.372)
Comprehensive vs. academic facility	1.139	(1.085–1.196)
Age	1.052	(1.049–1.054)
Female vs. male sex	1.233	(1.184–1.285)
Black vs. white race	1.18	(1.104–1.262)
Other vs. white race	0.739	(0.658–0.831)
Insured vs. not insured	0.686	(0.581–0.811)
Charlson–Deyo 1 vs. 0	1.262	(1.205–1.323)
Charlson–Deyo 2 vs. 0	2.005	(1.895–2.122)
Pathologic stage 2 vs. 1	1.422	(1.342–1.506)
Pathologic stage 3 vs. 1	3.23	(3.033–3.44)
High grade vs. low grade	1.42	(1.354–1.489)
Adjuvant chemotherapy	0.645	(0.608–0.684)

MIS has been widely adopted over the last two decades and our study confirms this national trend across all hospital types. Given recent work showing significant differences in mortality between teaching and non-teaching hospitals, it was unknown whether similar differences would be seen in MIS across hospital types [36]. While existing literature does not address the impact of hospital type and MIS in colon cancer, a similar question has been explored in rectal cancer. Rectal resections are known to be complex and demanding with regard to workup, technical aspects of



Type	2yr	5yr	p-value
Academic	91	76	<0.01
Comprehensive	90	73	
Community	87	58	

Fig. 3 Kaplan–Meier Survival Analysis of patients who had minimally invasive segmental colectomy for colon cancer at a hospital in the highest volume tertile at a by hospital type

the procedure, and management. Intuitively, this engenders differences in outcomes based on institution ability. In one study utilizing data from two prospective randomized trials by the Stockholm Rectal Cancer Study Group, Holm et al. found lower relative risk of local recurrence for patients treated at university hospitals and lower relative risk of death from rectal cancer when compared to those treated at community hospitals [29]. These studies were limited to rectal cancer and may not be readily applicable to colon cancer due to the differences in overall complexity of rectal versus colon biology and resections. Nonetheless, our findings were similar in that outcomes including 30- and 90-day mortality were lower at academic hospitals and overall patient survival was better in those patients treated at academic hospitals compared to community hospitals.

Recent work has shown that the variation in MIS utilization was primarily attributable to surgeon variation (62.8%) with a strong inverse relationship between years in practice and the rate of MIS colectomy utilization [37]. In rural or low-volume community centers, reaching the volume threshold for MIS proficiency (55 right-sided MIS colectomies and 62 left-sided MIS colectomies) would prove impossible in practicality [38, 39]. Therefore, patient referral to specialty-trained high-volume colorectal surgeons may improve MIS uptake [40]. Other potential surgeon-suggested solutions include site visits, mentoring, courses, and coaching for older or low-volume surgeons to increase use of MIS colectomy [40, 41]. This might result in lower technical complications and subsequently postoperative morbidity.

Differences in outcomes between hospitals have been described in oncologic care; however, the underlying reasons for these differences have yet to be defined. The difference in survival may be due to the better short-term perioperative outcomes at academic hospitals. For example, the better rates of complete resection and complete LN retrieval and analysis observed at academic hospitals may lower long-term rates of reoccurrence and improve overall survival. Additionally, academic hospitals might have higher volume surgeons for these operations. It has been previously shown that higher surgeon volume correlated with improved outcomes [42–51].

To examine the question of volume, we performed a subset analysis limited to hospitals in the highest volume tertile comparing outcomes by hospital types. While the overall

Table 4 Short-term surgical outcomes of patients who had minimally invasive segmental colectomy for colon cancer at a hospital in the highest volume tertile by hospital type

	Academic	Community	Comprehensive	All	*p* Value
Surgical margins					< 0.0001
Negative	11,419 (97.4%)	115 (95.04%)	18,346 (97.25%)	29,880 (97.3%)	
Positive	260 (2.22%)	6 (4.96%)	484 (2.57%)	750 (2.44%)	
< 12 Lymph Nodes Analyzed					< 0.0001
No	10,909 (93.05%)	96 (79.34%)	17,080 (90.54%)	28,085 (91.45%)	
Yes	815 (6.95%)	25 (20.66%)	1785 (9.46%)	2625 (8.55%)	
30-day readmission					0.33
No	10,992 (93.76%)	113 (93.39%)	17,901 (94.89%)	29,006 (94.45%)	
Yes	590 (5.03%)	8 (6.61%)	938 (4.97%)	1536 (5%)	
90-day mortality					< 0.0001
No	7953 (67.84%)	75 (61.98%)	12,500 (66.26%)	20,528 (66.84%)	
Yes	172 (1.47%)	2 (1.65%)	399 (2.12%)	573 (1.87%)	
Length of stay	5 (3–7)	5 (4–7)	5 (4–7)	5 (4–7)	< 0.0001

differences in outcomes were lessened, academic hospitals had improved outcomes including margin positivity and overall survival. A reason for the outcomes disparity between hospital types might be earlier adoption, increased standardization, and greater experience with MIS in academic settings. Previous studies have associated academic hospitals, especially with teaching status, in urban areas, and with higher volume, with greater uptake of laparoscopic colectomy [20–22]. Greater adoption of MIS in the academic settings may be secondary to the implementation of colorectal surgery fellowships, MIS courses, and integration of MIS into surgical education [40, 52–55]. While studies have shown greater MIS adoption in recent years by surgeons regardless of setting, there may be a lag effect across hospital types in expertise with MIS colectomies [56]. Regardless of the mechanism, our current data support overall superior outcomes following MIS colectomy for patients at academic hospitals at every stage of their care, despite a sicker patient population at baseline.

Our reported rates of compromised survival for patients treated at non-academic hospitals raise great concerns about the status of colon cancer management in the United States, since the majority of colon cancer cases in the country are not performed at an academic hospitals and MIS colectomy has universally increased across all hospital types. Additionally, dedicated staff and facilities for multidisciplinary oncologic care are possible causes of improved patient outcomes at academic hospitals [57, 58]. However, 61.4% of all MIS segmental colectomy volume occurred at comprehensive cancer facilities with multidisciplinary teams, and the difference in survival outcomes persisted.

Overall, our data support regionalization and the referral of patients with colon cancer to academic hospitals; however, the majority of laparoscopic and conventional colectomies for colon cancer occur in non-academic settings, and realistically, this paradigm is unlikely to rapidly shift. Therefore, high-performing academic centers and specialized colorectal surgeons may need to help improve long-term outcomes in low-performing non-academic centers through increased education, surgical coaching, and simulation. The technical skill of individual surgeons has been shown to have an impact on long-term patient outcomes and wider implementation and dissemination of surgical coaching programs for performance improvement may help offset differences in hospital settings [59, 60]. Another possible solution is to increase surgical simulation for procedures where differences in outcomes are seen among hospital settings [61]. Surgical "boot camps" have also been shown to be effective in increasing the technical skills of trainees and could be offered at all levels for certain procedures [62].

Our study has several limitations. Although the NCDB contains comprehensive and well-validated data [35], retrospective analyses are affected by selection and indication biases for MIS and location. By adjusting for clinical and demographic characteristics, in our multivariable analysis, we attempted to minimize unforeseen biases. Any potential for the selection bias for MIS should be generalizable across hospital types and, therefore, our findings remain informative. Although the NCDB is increasing in granularity, a detailed analysis of patient anatomic and surgeon factors leading to MIS vs. open surgery is incomplete. This study analyzes stages I-III colon adenocarcinoma in aggregate, and from this analysis cannot be extrapolated to Stage IV tumors. Details regarding adjuvant chemotherapy including dose, type, and completion are not included in the NCDB. Survival is reported as overall survival, and no disease specific survival. Although retrospective databases have limitations, this study would be impossible to conduct as a prospective trial, randomizing patient to a location of care and a surgical technique and thus gives the best understanding of the benefits of MIS in an academic setting for this cohort.

While MIS techniques are well adopted and widespread across hospital types for colon cancer patients, receipt of treatment at an academic center is associated with superior oncological outcomes and survival compared to community and comprehensive community hospitals. Technical aspects of surgery like margin positivity and inadequate LN retrieval and analysis are important. These results, however, emphasize that despite the alleged simplicity of a surgical procedure for cancer, cancer care is more complex, and outcomes are clearly not solely dependent on the technical aspects of a surgical procedure. Thus, colon cancer cases may need referral and thorough evaluation by multidisciplinary teams including medical and radiation oncologist, radiologists, and surgeons. This multidisciplinary setting in academic hospitals may be responsible for the improved outcomes from minimally invasive colectomy for cancer. Our data add to the growing body of evidence favoring regionalization for even commonly performed procedures. These findings may provide important information for colon cancer patients, referring physicians, and surgeons about the role of hospital type in management of colon cancer and its impact on outcomes.

Compliance with ethical standards

Disclosures Kyle Freischlag, Mohamed Adam, Megan Turner, Brain Ezekian, Joshua Watson, Paul M. Schroder, Christopher Mantyh, and John Migaly have no conflicts of interest or financial ties to disclose.

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