RESEARCH ARTICLE JSLS

Improved Morbidity, Mortality, and Cost with Minimally Invasive Colon Resection Compared to Open Surgery

Hazim Hakmi, MD, Leo Amodu, MD, MPH, Patrizio Petrone, MD, PhD, MPH, MHSA, Shahidul Islam, DrPH, MPH, Amir H. Sohail, MD, MPH, Michael Bourgoin, MA, Toyooki Sonoda, MD, Collin E. M. Brathwaite, MD, MS

ABSTRACT

Background and Objectives: Despite the growth of minimally invasive surgery (MIS) in many specialties, open colon surgery is still routinely performed. The purpose of this study was to compare outcomes and costs between open colon and minimally invasive colon resections.

Methods: We analyzed outcomes between January 1, 2016 and December31, 2018 using the Vizient® clinical database. Demographics, hospital length of stay, readmissions, complications, mortality, and costs were compared between patients undergoing elective open and minimally invasive colon resections. For bivariate analysis, Wilcoxon rank-sum test was used for continuous variables and χ^2 test was used for categorical variables. Multiple Logistic and Quintile regression were used for multivariable analyses.

Results: A total of 88,405 elective colon resections (open: 56,599; minimally invasive: 31,806) were reviewed. A significantly larger proportion of patients undergoing minimally invasive surgery were obese (body mass index > 30) compared to those undergoing open surgery (71.4% vs. 59.6%; $p < 0.0001$). As compared to minimally invasive colectomy, open colectomy patients had: a longer median length of stay [median (range): 7 (4–13) days vs. 4 (3 – 6) days, $p < 0.0001$], higher 30-day readmission rate [n = 8557 (15.1%) vs. 2815 (8.9%), $p < 0.0001$], higher mortality [n = 2590 (4.4%) vs. 107 (0.34%), $p < 0.0001$], and a higher total direct cost [median (range): $13,582 (9041–23,094) vs. $9013 (6748 – 12,649), $p < 0.0001$]. Multivariable models confirmed these findings.

Conclusion: Minimally invasive colon surgery has clear benefits in terms of length of stay, readmission rate, mortality and cost, and the routine use of open colon resection should be revaluated.

Key Words: Colorectal surgery, Open approach, Laparoscopic, Robotic, Minimally invasive surgery.

INTRODUCTION

With an estimated 2% annual increase in incidence of colorectal cancer among patients aged less than 50 years and the high prevalence of diverticular disease, the overall volume of colon procedures has been rising.[1,2] In the early 1990s, laparoscopic colorectal surgery, despite its longer operative time, was determined to be a safe alternative to open resection, and was associated with decreased postoperative morbidity and shorter length of hospital stay.[3,4]

In recent years, the widespread use of robotic surgery in various surgical specialties has also led to the adoption of robotic surgery in the field of colon surgery, with a fourfold increase in robotic-assisted colorectal procedures witnessed between 2009 and 2012.[5,6]

Current practice in colon surgery includes all three surgical approaches (open, laparoscopic, and robotic). Open approach is still believed to be the gold standard in technically challenging cases when the procedure cannot be performed safely with the laparoscopic or robotic approach.

Evidence suggests that the initial cost of procuring robotic equipment is a major hurdle for some hospitals.[7]

Department of Surgery, NYU Langone Hospital—Long Island, Mineola, NY. (Drs. Hakmi, Amodu, Petrone, Sohail, Sonoda, and Brathwaite)

Department of Performance Analytics, NYU Langone Hospital—Long Island, Mineola, NY. (Mr. Bourgoin)

Division of Health Services Research, NYU Long Island School of Medicine, Mineola, NY. (Dr. Islam)

Conflict of interests: none.

Informed consent: Dr. Collin E.M. Brathwaite declares that written informed consent was obtained from the patient/s for publication of this study/report and any accompanying images.

Address correspondence to: Dr. Collin E.M. Brathwaite, Department of Surgery NYU Langone Hospital—Long Island, 222 Station Plaza North, Suite 300, Mineola, NY 11501, Telephone: 516-663-3913, E-mail: collin.brathwaite@nyulangone.org.

DOI: 10.4293/JSLS.2021.00092

Interestingly, there is paucity of data on whether this high initial cost can be offset by the associated advantages, such as reduced operative times, improvements in readmission rates, and lower complication rates. Further, in the elderly and obese populations (one-third of the population in the U.S. is classified as obese) robotic approach may have some benefits.[8]

Despite the increase in the performance of robotic surgery and minimally invasive surgery (MIS) in general surgery, much of colon surgery is still being performed as open surgery in the U.S. The purpose of this study was to compare outcomes and costs between open colon and minimally invasive colon resections performed at major academic medical centers in the U.S.

METHODOLOGY

Data was obtained from the Vizient® clinical database, a comparative database with discharge and line-item data from more than 350 member institutions, including 97% of academic medical centers in the U.S. with 8.5 million inpatient encounters per year. The data included patients undergoing open or minimally invasive colon resections between January 1, 2016 and December 31, 2018, data on demographics (age, sex, and racial background), body mass index (BMI), length of hospital stay (days), 30-day readmission, complications, mortality, and total direct costs incurred (USD) were retrieved.

These data elements were defined by use of ICD-10 code and are limited by the corresponding issues that come as a result of utilizing billing data. As such, the specific modality of minimally invasive surgery (laparoscopic vs robotics) could not be well defined. BMI and complications were also defined by code and as such patients without assigned codes were excluded (BMI) or assumed not to have complications. These are standard limitations of relying on coded data and are well tolerated in the industry.

All continuous variables were assessed for normality and outliers using formal statistical, extreme observations, histograms, and probability plots. Continuous variables were summarized as mean (standard deviation) or median (interquartile range [IQR]) as appropriate, while frequency (percentage) was determined for categorical variables.

For bivariate analysis, Wilcoxon rank-sum test was used for continuous variables, while χ^2 test was used for categorical variables. Baseline and outcome measures, (length of hospital stay, 30-day readmission rate, mortality rate, and total direct costs) were compared between the open and laparoscopic colon resection groups.

Multivariate logistic regression models were used to determine the odds of mortality, 30-day readmissions in open resection vs. minimally invasive resection, as well as the odds of mortality by age, gender (male vs. female) and race (White, Black, other Nonwhite) for all colon resections.

All results were considered statistically significant at $P <$ .05 level of significance. All analyses were performed using SAS version 90.4 (SAS Institute Inc., Cary, NC).

RESULTS

The total number of elective colon resections undertaken between January 1, 2016 and December 31, 2018 were 88,405. Of these, 56,599 were open resections while 31,806 were minimally invasive. Patients undergoing open resections were significantly older than those undergoing minimally invasive resection (61.5 years vs. 60.8 years, $P <$ .001), and there was a female preponderance in both open and minimally invasive groups (52.8% in open, and 51.2% in minimally invasive, $P <$ .001 for all comparisons). Compared to patients undergoing open resection, a significantly higher proportion of patients undergoing minimally invasive resections were obese (defined as having a BMI > 30 kg/m2); 71.4% vs. 59.6%, $P <$ .0001). **Table 1** summarizes the demographic characteristics of the study groups.

MIS was associated with superior outcomes compared to open surgery. The median length of stay (LOS) was significantly longer for open resection vs. MIS (7 days vs. 4 days, $P <$ .0001). Similarly, 30-day readmission and mortality rates were both significantly lower for the MIS group compared to the open group (30-day readmission rates: 8.9% vs. 15.1%, $P <$ .0001), mortality rates: 0.34% vs. 4.4%, $P <$ .0001) Open resection was associated with a significantly higher median total direct cost vs. MIS resections ($13,582 vs. $9,013, $P <$ .0001). **Table 2** summarizes the bivariate comparison of outcomes between the two study groups.

On multivariate analysis, open resection patients had 13 times greater odds of mortality at discharge than MIS surgery patients (odds ratio [OR] 13.7, $P <$ .0001). Race and sex were predictors of mortality; Nonwhite patients had significantly higher odds of mortality in comparison with White patients (OR 1.44 for Black patients, 1.43 for other Nonwhite races, $P <$ .0001 for both comparisons) while OR for mortality among females was 0.65, $P <$ .0001.

Table 1.
Demographic Characteristics

Variable	Open (n = 56,599)	Laparoscopic (n = 31,806)	Overall (n = 88,405)	*p*-Value
Age (Year), Median (Interquartile range)	61.5 (50.6–70.8)	60.8 (50.8 – 70.3)	61.3 (50.7 – 70.6)	<0.001
Sex, n (%)				<0.0001
Male	26,723 (47.2)	15,517 (48.8)	42,240 (48.8)	
Female	29,873 (52.8)	16,289 (51.2)	46,162 (52.2)	
Race				<0.0001
White	41,661 (73.6)	24,421 (76.8)	66,082 (74.7)	
Black	8,231 (14.5)	3,419 (10.7)	11,650 (13.2)	
Other Nonwhite	6,707 (11.9)	3,966 (12.5)	10,673 (12.1)	
Obese status, n (%)*				<0.0001
BMI ≥ 30 (kg/m^2)	9,914 (59.6)	4,867 (71.4)	14,781 (63.0)	
BMI < 30 (kg/m^2)	6,719 (40.4)	1,947 (28.6)	8,666 (37.0)	

BMI, body mass index.
*BMI was missing for n = 64,958 patients. Obesity status was estimated using n = 16,663 in the Open group and n = 6,814 in the Laparoscopic group.

Table 3 summarizes the results of logistic regression analysis for mortality.

Adjusted for all other factors, open colon surgery was associated with a significantly higher odds of readmission vs. MIS (OR 1.82, $P < .0001$). Age, gender, and race were also independently associated with 30-day readmission. **Table 4** summarizes the multivariate regression analysis results for 30-day readmission.

After adjusting for all other factors, **Table 5** shows the median LOS was 3.4 days higher for patients who had open colon surgery compared to MIS. Age, sex, and race were independently associated with LOS, while **Table 6** shows the median cost was $4,520 higher for patients who had open colon surgery compared to MIS. For every 10-year increase in age, median cost increased by $177. Female patients had $1,082 lower median cost than male patients. Compared to White patients, Black and Nonwhite patients had higher cost ($1,474 and $731, respectively).

DISCUSSION

Colon surgical operations have increased in the past two decades, with more than 10,000 colon surgeries performed in the U.S. annually. The new U.S. Preventive Services Task Force recommendations for colorectal cancer screening starting at 45 years of age, and the increasing use of novel less invasive modalities for colorectal cancer screening has led to detection of a large volume of early-stage colorectal malignancy. Besides operative interventions for colon cancer, surgery for benign colon pathology, particularly diverticular disease of the colon, has also increased in the U.S. More than 10,000 colon resections are performed annually in the U.S., with an increased use of MIS for both emergent and elective colon resections.

Table 2.
Bivariate Comparisons of Outcomes

Variable	Open (n = 56,599)	Laparoscopic (n = 31,806)	*p*-Value
Length of Stay (days), Median (Interquartile range)	7 (4 – 13)	4 (3 – 6)	<0.0001
30-day Re-admission, n (%)	8,557 (15.1)	2,815 (8.9)	<0.0001
Mortality, n (%)	2,590 (4.4)	107 (0.34)	<0.0001
Total Direct Cost ($), Median (Interquartile range)	13,582 (9,051 – 23,094)	9,013 (6,748 – 1,2649)	<0.0001

Table 3.
Multiple Logistic Regression Model for Mortality

Factor	Odds Ratio (95% Confidence Interval)	*p*-Value
Procedure		
Laparoscopic	reference	—
Open	13.7 (11.3 – 16.7)	< 0.0001
Age (for each 10-year increase)	1.37 (1.33 – 1.41)	< 0.0001
Sex		
Male	reference	—
Female	0.65 (0.60 – 0.70)	< 0.0001
Race		
White	reference	—
Black	1.44 (1.29 – 1.60)	< 0.0001
Other Nonwhite	1.43 (1.27 – 1.60)	< 0.0001

*C-statistic-0.75.

Jacobs et al. described the safety of minimally invasive laparoscopic colon resections in 1991, including hemicolectomies, sigmoidectomies, low anterior resections, and abdomino-perineal resections.[9] MIS resections were greeted with caution and doubt as colon resections were regarded as major operations in comparison to MIS of the gallbladder and appendix. Oncologic MIS colon resections were initially presumed to have high recurrence rates at port sites, raising doubts about the efficacy of MIS in oncologic resections. This led to a slow adoption of colon MIS in the 1990s with only 8% of colon resections in the U.S. performed by laparoscopy alone, and another 8% performed with laparoscopic assistance. By 2000 new

Table 4.
Multiple Logistic Regression Model for Readmission

Factor	Odds Ratio (95% Confidence Interval)	*p*-Value
Procedure		
Laparoscopic	reference	—
Open	1.82 (1.74 – 1.91)	< 0.0001
Age (for each 10-year increase)	0.97 (0.96 – 0.98)	< 0.0001
Sex		
Male	reference	—
Female	0.95 (0.92 – 0.99)	0.022
Race		
White	reference	—
Black	1.19 (1.12 – 1.26)	< 0.0001
Other Nonwhite	0.99 (0.93 – 1.05)	0.672

*C-statistic-0.58.

Table 5.
Quantile (Median) Regression Model for Length of Stay

Variable	*Estimate (95% Confidence Interval)	*p*-Value
Procedure		
Laparoscopic	reference	—
Open	3.38 (3.32, 3.44)	< 0.0001
Age (for each 10-year increase)	0.166 (0.147, 0.186)	< 0.0001
Sex		
Male	reference	—
Female	−0.452 (−0.518, −0.386)	< 0.0001
Race		
White	reference	—
Black	1.06 (0.94, 1.18)	< 0.0001
Other Nonwhite	0.233 (0.153, 0.313)	< 0.0001

*Regression coefficients were estimated via Quantile (Median) regression.

Table 6.
Quantile Regression Model for Cost

Variable	*Estimate (95% Confidence Interval)	*p*-Value
Procedure		
Laparoscopic	reference	—
Open	4,520 (4409, 4630)	< 0.0001
Age (for each 10-year increase)	177.4 (143.2, 211.7)	< 0.0001
Sex		
Male	reference	—
Female	−1,081.6 (−1178.8, −984.5)	< 0.0001
Race		
White	reference	—
Black	1,474.4 (1265.0, 1683.8)	< 0.0001
Other Nonwhite	731.1 (551.0, 911.2)	< 0.0001

*Regression coefficients were estimated via Quantile (Median) regression.
This model includes patients with >$0 cost (n = 86,347).

evidence showed favorable outcomes in laparoscopic colon resections in comparison to open colon resections (OCR). The turn of the century was also characterized by the advent data regarding the safe use of robotic colon resections and single-incision laparoscopic colon resections.[10-13] Those improved outcomes were in conjunction with a steep reduction in colon MIS operative times (without jeopardizing clinical outcomes) after almost 40 colon MIS, highlighting a reasonable learning curve.

Short-Term Outcomes

Studies initially showed modestly improved short-term outcomes when comparing MIS to OCR. One of the most important outcomes, hospital LOS, is significantly lower in patients undergoing colon MIS due to multiple factors;[14] Reduced postoperative complications, including the most common reported complication after colon surgery, postoperative ileus is curtailed not only due to the application of enhanced recovery programs but also due to the reduced pain and ability of patients to ambulate earlier in MIS. Earlier tolerance of oral intake was also noted in colon MIS.[15] Postoperative morbidity including infectious (wound infections, abdominal abscesses, respiratory and urinary tract infections, bacteremia) and noninfectious (arrhythmias, ileus, bleeding, intestinal obstruction, deep venous thrombosis) complications were lower in colon MIS along with a lower short term mortality rate, mirroring the results of our study.[16]

Oncologic Outcomes

In regard to long term survival and disease-free period for oncologic colon resections, the initial hypothesis that inadequate margins and incomplete resection margins along with trocar site tumor recurrence had a great impact on the delay of adoption of colon MIS, along with a clinical trial in 2000 concluding inferiority of colon MIS to OCR in oncologic pathologies.[17] Similar results were not reproducible. Most clinical trials performed afterwards, showed noninferiority of colon MIS to OCR.[18] The use of wound protectors and slow desufflation with intracorporeal trocars have helped reduce the aforementioned recurrence rates. In recent trials and metanalysis, 3- and 5-year progression free survival were similar between groups. Recurrence rates, whether local, at wound site or distant metastasis were similar between both colon MIS and OCR. Overall cancer related mortality rates were also similar between groups. The most essential factor in disease-free survival in most studies was not the surgical approach used, but the surgeons experience with oncologic colon resections and specialty, which showed a tendency towards fewer local recurrences.[19]

Cost/Benefit

When comparing costs between colon MIS and OCR, it's essential to include the financial impact of complications, morbidities, readmission rates and length of hospital stay in the overall cost. Comparing the costs of either laparoscopic instruments or robotic instruments, consoles and video towers, the cost of colon MIS will exceed that of the OCR approach, as was initially published.[20] If robotic and laparoscopic equipment was added as capital cost that would greatly reduce cost benefits of MIS. Initial operative time also plays a role when comparing cost benefits of different approaches, keeping in mind that colon MIS was a fairly new approach that started only two to three decades ago.

Although more surgeons are trained to perform MIS, less than half of the colon resections are performed using MIS approach. Thus, the time to train and be competent with the minimally invasive approach adds an additional cost, but as surgical programs continue to train surgeons and residents in the use of minimally invasive techniques, and institutions continue to utilize laparoscopic and robotic equipment, the cost of colon MIS will continue to drop.

Overall, adding complications, hospital LOS, discharge to home versus a rehabilitation facility, along with current reduced operative times in MIS, the overall cost benefit of OCR will far exceed that of the colon MIS. Current studies estimate cost savings between 500 and 8,000 USD between colon MIS and OCR.[21] With these improved cost benefits, colon MIS would be beneficial to patients instead of OCR.

Training/Learning Curve

The laparoscopic learning curve continues to steepen with rapid learning of colon MIS. The use of minimally invasive techniques in surgical training for most procedures has led to an easier adoption of colon MIS, due to prior experience with laparoscopic instrumentation.

Recent recommendations for the assessment of the MIS learning curve suggested that it should not be limited to a decrease in operative time and should also include the conversion and complication rates. Multiple case series and observational studies have shown that operative time may or may not decrease after 50–90 colon MIS, owing to the increased confidence of the surgeon and the application of minimally invasive techniques in high complexity patients, but conversion from MIS and OCR tends to decrease after 30–50 operations.[22] Robotic surgery, although limited to centers with access to robotic equipment and consoles, has a faster learning trend with proficiency levels approached after 25–30 cases. Robotic surgery has the advantage of 3-dimensional and ergonomic controls, facilitating surgical intervention in highly complex surgeries.[23]

Surgeons may also benefit from professionally reviewed recorded operative procedures to further enhance their technique, improve outcomes and reduce operative time.

THE FUTURE OF COLON MIS

Improved outcomes, decreased morbidity and mortality, and cost savings when performing colon MIS are all factors that should drive surgeons to adopt the minimally invasive approach as the gold standard for colon resections. An incentive to help surgeons steer towards MIS could be by changing the reimbursement rates for laparoscopic and robotic colon resections, as a recent study by Keller et al., showed lower reimbursements of colon MIS in comparison to OCR. They suggested that a 10% –20% increase in reimbursements would result in cost savings with colon MIS due to reduced hospital LOS, complications, comorbidities, and would lead to faster adoption of that approach.[24]

As laparoscopic and robotic procedures are performed in academic centers, surgical residents will be more likely to perform colon MIS, due to training in those approaches, easier use of instruments, and faster learning curves once they are surgeons.[25,26]

We hope that reinforcing the stark difference in outcomes, cost benefit, morbidity, and mortality, will aid in that transition toward colon MIS.

STRENGTHS AND LIMITATIONS

This is one of the largest retrospective studies comparing outcomes of patients undergoing elective colon MIS vs. OCR with 88,000 patients included. We compared high impact outcomes including LOS, morbidity, mortality, and total direct cost of admission including costs of the procedure and extra costs encountered due to complications and readmissions. In this study, we could not subcategorize the colon MIS into laparoscopic, hand-assisted, single port, and robotic to differentiate and compare groups due to limitations of the data gathered from the database. Our analysis did not match colon MIS to open group in regard to baseline comorbidities which can lead to higher complication rates in either group.

CONCLUSION

Minimally invasive colon surgery has clear benefits in terms of LOS, readmission rate, mortality, and cost. Open colon surgery should not be considered the gold standard approach for colon resections.

References:

1. Siegel RL, Miller KD, Goding Sauer A, et al. Colorectal cancer statistics, 2020. *CA A Cancer J Clin*. 2020;70(3):145–164.

2. Siegel RL, Fedewa SA, Anderson WF, et al. Colorectal cancer incidence patterns in the United States, 1974-2013. *J Natl Cancer Inst*. 2017;109(8):djw322.

3. Phillips EH, Franklin M, Carroll BJ, Fallas MJ, Ramos R, Rosenthal D. Laparoscopic colectomy. *Ann Surg*. 1992;216 (6):703–707.

4. Fujii S, Tsukamoto M, Fukushima Y, et al. Systematic review of laparoscopic vs open surgery for colorectal cancer in elderly patients. *WJGO*. 2016;8(7):573–582.

5. Robotic surgery evaluation: 10 years too late. *Lancet*. 2016;388(10049):1026.

6. Yeo HL, Isaacs AJ, Abelson JS, Milsom JW, Sedrakyan A. Comparison of open, laparoscopic, and robotic colectomies using a large national database: outcomes and trends related to surgery center volume. *Dis Colon Rectum*. 2016;59(6):535–542.

7. Liao G, Chen J, Ren C, et al. Robotic versus open gastrectomy for gastric cancer: a meta-analysis. *PLoS One*. 2013;8(12): e81946.

8. Rimm A. Prevalence of obesity in the United States. *JAMA*. 2014;312(2):189.

9. Jacobs M, Verdeja JC, Goldstein HS. Minimally invasive colon resection (laparoscopic colectomy). *Surg Laparosc Endosc*. 1991;1(3):144–150.

10. Guller U, Jain N, Hervey S, Purves H, Pietrobon R. Laparoscopic vs open colectomy: outcomes comparison based on large nationwide databases. *Arch Surg*. 2003;138(11):1179–1186.

11. Davis BR, Yoo AC, Moore M, Gunnarsson C. Robotic-assisted versus laparoscopic colectomy: cost and clinical outcomes. *JSLS*. 2014;18(2):211–224.

12. Siddiqui MR, Sajid MS, Khatri K, Cheek E, Baig MK. Elective open versus laparoscopic sigmoid colectomy for diverticular disease: a meta-analysis with the Sigma trial. *World J Surg.* 2010;34 (12):2883–2901.

13. Mushtaq HH, Shah SK, Agarwal AK. The current role of robotics in colorectal surgery. *Curr Gastroenterol Rep.* 2019;21(3):11.

14. Song XJ, Liu ZL, Zeng R, Ye W, Liu CW. A meta-analysis of laparoscopic surgery versus conventional open surgery in the treatment of colorectal cancer. *Medicine (Baltimore).* 2019; 98(17):e15347.

15. Sun J, Jiang T, Qiu Z, et al. Short-term and medium-term clinical outcomes of laparoscopic-assisted and open surgery for colorectal cancer: a single center retrospective case-control study. *BMC Gastroenterol.* 2011;11:85.

16. Braga M, Vignali A, Gianotti L, et al. Laparoscopic versus open colorectal surgery: a randomized trial on short-term outcome. *Ann Surg.* 2002;236(6):759–766; discussion 767.

17. COLOR Study Group. COLOR: a randomized clinical trial comparing laparoscopic and open resection for colon cancer. *Dig Surg.* 2000;17(6):617–622.

18. Morneau M, Boulanger J, Charlebois P, et al. Laparoscopic versus open surgery for the treatment of colorectal cancer: a literature review and recommendations from the Comité de l'évolution des pratiques en oncologie. *Can J Surg.* 2013; 56(5):297–310.

19. Hilska M, Roberts PJ, Kössi J, Paajanen H, Collan Y, Laato M. The influence of training level and surgical experience on survival in colorectal cancer. *Langenbecks Arch Surg.* 2004; 389(6):524–531.

20. Philipson BM, Bokey EL, Moore JW, Chapuis PH, Bagge E. Cost of open versus laparoscopically assisted right hemicolectomy for cancer. *World J Surg.* 1997;21(2):214–217.

21. Keller DS, Zhang J, Steele SR. A paradigm shift in physician reimbursement: a model to align reimbursement to value in laparoscopic colorectal surgery in the United States. *Dis Colon Rectum.* 2020;63(10):1446–1454.

22. Dinçler S, Koller MT, Steurer J, Bachmann LM, Christen D, Buchmann P. Multidimensional analysis of learning curves in laparoscopic sigmoid resection: eight-year results. *Dis Colon Rectum.* 2003;46(10):1371–1378.discussion 1378-1379.

23. Bokhari MB, Patel CB, Ramos-Valadez DI, Ragupathi M, Haas EM. Learning curve for robotic-assisted laparoscopic colorectal surgery. *Surg Endosc.* 2011;25(3):855–860.

24. Howlader N, Noone AM, Krapcho M, Miller D, Brest A, Yu M, Ruhl J, Tatalovich Z, Mariotto A, Lewis DR, Chen HS, Feuer EJ, Cronin KA (eds). SEER Cancer Statistics Review, 1975-2018, National Cancer Institute. Bethesda, MD, https://seer.cancer.gov/csr/1975_2.

25. U.S Preventative Services Task Force Colorectal Cancer: Screening. Available at: https://www.uspreventiveservicestaskforce.org/uspstf/recommendation/colorectal-cancer-screening.

26. Lin J, Perdue L, Henrikson N, et al. Screening for Colorectal Cancer: An Evidence Update for the U.S. Preventive Services Task Force. JAMA. 2021;325(19):1978–1998.