

Predicting Opportunities to Increase Utilization of Laparoscopy for Rectal Cancer
Short title: Lap Rectal Cancer Predictors

Deborah S. Keller, MS MD, Baylor University Medical Center, Dallas, TX

Jiejing Qiu, MS, Healthcare Economics and Outcomes Research, Medtronic, Mansfield, MA

Anthony J Senagore, MS MD MBA, University of Texas Medical Branch at Galveston, Galveston, TX

Abstract Word Count: 300/300, Manuscript Count: 2224

Poster Presentation, SAGES Annual Conference, March 21-25, 2017, Houston, TX

The authors received no funding for this manuscript.

Corresponding Author:

Deborah S Keller, MS MD

Division of Colon and Rectal Surgery, Department of Surgery

Baylor University Medical Center

3500 Gaston Street, R-1013

Dallas, TX 75246

Phone: (646) 337-7184

Fax: (214) 820-7272

E-mail: debby_keller@hotmail.com

Abstract

Background: Despite proven safety and efficacy, rates of laparoscopy for rectal cancer in the US are low. With reports of inferiority **with laparoscopy** compared to open surgery, and movements to develop accredited centers, investigating utilization and predictors of laparoscopy are warranted. Our goal was to evaluate current utilization and identify factors impacting use of laparoscopic surgery for rectal cancer.

Methods: The PremierTM Hospital Database was reviewed for elective inpatient rectal cancer resections (**1/1/2010-6/30/2015**). Patients were identified by ICD-9-CM diagnosis codes, then stratified into open or laparoscopic approaches by ICD-9-CM procedure codes or billing charge. Logistic multivariable regression identified variables predictive of laparoscopy. The Cochran-Armitage test assessed trend analysis. The main outcome measures were trends in utilization and factors independently associated with use of laparoscopy.

Results: 3,336 patients were included- 43.8% laparoscopic(n=1,464) and 56.2% open(n=1,872). Use of laparoscopy increased from 37.6% to 55.3% during the study period(p<0.0001). General surgeons performed the majority of all resections, but colorectal surgeons were more likely to approach rectal cancer laparoscopically(41.31% vs. 36.65%, OR 1.082, 95% CI[0.92, 1.27], p<0.3363). Higher volume surgeons were more likely to use laparoscopy than low volume surgeons(OR=3.72, 95%CI[2.64, 5.25], p<0.0001). Younger patients(OR 1.49, 95% CI[1.03, 2.17], p=0.036) with minor(OR 2.13, 95% CI[1.45, 3.12], p<0.0001) or moderate illness severity(OR 1.582, 95% CI[1.08, 2.31], p<0.0174) were more likely to receive a laparoscopic resection. Teaching

hospitals(OR=0.842, 95% CI[0.710, 0.997], p=0.0463) and hospitals in the Midwest (OR=0.69, 95% CI[0.54, 0.89], p=0.0044) were less likely to use laparoscopy. Insurance status and hospital size did not impact use.

Conclusions: Laparoscopy for rectal cancer steadily increased over the years examined. Patient, provider, and regional variables exist, with hospital status, geographic location, and colorectal specialization impacting the likelihood. However, surgeon volume had the greatest influence. These results emphasize training and surgeon-specific outcomes to increase utilization and quality in appropriate cases.

Keywords: Laparoscopic colorectal surgery; rectal cancer; surgical quality; surgeon volume

Introduction

Laparoscopic colorectal surgery is the new standard of care and a key enabler of enhanced recovery programs (1). Despite the clinical benefits, reported rates of laparoscopic surgery for rectal cancer in the United States are low (2, 3). The reasons for the lower than expected utilization are multifactorial, including the long learning curve, technical challenges of working in an anatomically confined space, and limits in instrumentation and visibility (4–8). While the technique is difficult, no compromises in patient safety or oncological outcomes, including rate of conservative sphincter surgery, length of hospital stay, post-surgical complications, number of affected/isolated lymph nodes or affected circumferential and distal margins, were reported during the learning curve for laparoscopic rectal cancer resections (9). Another key reason for lower than expected utilization may be that the oncologic and long-term safety of the technique was unclear (10).

The safety and feasibility of laparoscopy was first proven for colon cancer (11–19); then, controlled studies were extended to rectal cancer. Several large case series and single-institution trials showed that laparoscopy was safe and feasible for rectal cancer (20). Results from the COLOR II, COREAN, and MRC CLASICC randomized-controlled trials supported equivalent outcomes for laparoscopic and open rectal cancer resections (16, 21–25). Findings from recent studies questioned these results. The long-term outcomes from the ALaCaRT and ASOCOG Z6051 trials demonstrated laparoscopic resection failed to meet the criterion for noninferiority compared with open surgery in curative rectal cancer resections (26, 27). With this lack of support for routine use of

laparoscopic surgery, and movements to standardize techniques and develop centers of excellence, investigating current utilization and predictors of laparoscopy for rectal cancer resection are warranted.

Our goal was to evaluate the current utilization and identify factors impacting use of laparoscopic surgery for rectal cancer. Our hypothesis was that by identifying these factors, surgeons could proactively work to safely increase laparoscopic approaches and surgical quality for rectal cancer patients.

Methodology and Materials

The Premier Hospital Database (Premier, Charlotte, NC, USA) was reviewed from January 1, 2010 through June 30, 2015 to identify patients with rectal cancer who underwent elective rectal resection. The Premier Hospital Database represents approximately 1 out of every 5 United States inpatient hospital discharges, and is one of the largest hospital-level resource utilization and economic databases in the U.S. Specifically, there are approximately 600 hospitals contributing data on over 5 million inpatient discharges per year. Hospitals included in the database are a national representation in terms of regional distribution, urban versus rural hospital, teaching versus non-teaching institutions, and hospital bed size. Discharge-level data includes information on patient and provider characteristics, International Classification of Diseases 9th revision Clinical Modification (ICD-9-CM) diagnosis and procedure codes, hospital resource utilization such as specific device usage, medications and laboratory services, and charges/cost data on all entries.

Rectal cancer patients were identified by International Classification of Diseases, Ninth Revision [ICD-9] diagnosis codes (154.1 and 230.4). Patients were eligible and included if over 18 years of age and had an elective rectal resection performed via an abdominal approach. Patients were excluded if under 18 years of age, undergoing an emergent procedure, had metastatic disease, if rectal cancer was not the primary diagnosis, no resection was performed, or a procedure was performed via a robotic, anorectal, or endoscopic approach. Eligible patients were then stratified into laparoscopic or open groups based on ICD-9 procedure codes (laparoscopic 48.42, 48.51, 48.52, 48.62, 48.64) or open 46.04, 48.43, 48.52, 48.62, 48.64). For some ICD9 procedures codes (48.40, 48.50, 48.49, 48.59, 48.69, 48.63, 48.65) that were not able to differentiate open from laparoscopic alone, the presence of combination of laparoscopic ICD9 procedure code (54.21, 54.51) and billing data were used to further separate the laparoscopic procedure from open procedure. Laparoscopic converted to open patients were included in the laparoscopic cohort for intention to treat analysis.

Univariate analysis was used to compare the laparoscopic and open groups, with student t-tests and chi-squared statistics for continuous and categorical variables, respectively. A multivariable logistic regression model was used to identify variables predictive of use of laparoscopy for rectal cancer. The regression model was constructed adjusted for patient, provider and hospital characteristics. Variables evaluated in the analysis included patient age, gender, race, year of surgery (2010-2015), insurance status (Medicaid, Medicare, Private Commercial, Other), severity of illness (3M™ All Patient Refined DRG (APR

DRG) Classification System severity scores), hospital region (Northeast, Midwest, South, West), surgeon specialty, surgeon colon cases/year, urban vs. rural hospital, teaching vs. non-teaching private hospital, and hospital bed size. The APR-DRG severity of illness scale was used to provide an evaluation of resource use and clinical outcomes. (28). Adjusted Odds Ratios (OR) were reported for all the predictors included in the model, along with 95% confidence interval and p-value. The Cochran-Armitage test was used for trend analysis. P-value less than 0.05 was considered as statistically significance. All analyses were performed using SAS software, version 9.4 (Cary, NC).

The data in Premier are de-identified and compliant with the Health Insurance Portability and Accountability Act (HIPAA), and therefore exempt from Institutional Review Board (IRB) approval (45 CFR §46.001(b) (4)).

Results

3,336 patients were included in the analysis- 43.8% laparoscopic (n=1,464) and 56.2% open (n=1,872). Overall, the use of laparoscopy steadily increased from 37.6% to 55.3% during the study period, (p<0.0001). There were inherent differences in the patients undergoing each approach (Table 1). The laparoscopic cohort patients were significantly younger (p<0.001), with lower disease severity (p<0.001), and more privately insured patients than the open cohort (p<0.001). General surgeons performed the majority of all resections, but colorectal surgeons were more likely to approach rectal cancer laparoscopically (41.31% vs. 36.65%, p=0.023). High volume (> 20 cases per year) and medium volume physicians (10-20 cases per year) performed significantly more cases

laparoscopic than open ($p < 0.001$). There were regional differences seen in use of laparoscopy for rectal cancer. Most cases, both open (43.64%) and laparoscopic (43.99%) were performed in the South. There were significantly more open cases in the Midwest (19.66% open vs. 16.53% laparoscopic) and significantly more laparoscopic cases in the Northeast (22.34% laparoscopic vs. 18.70% open), ($p = 0.018$). In the univariate analysis, there were no significant differences seen in case approach by hospital bed size, teaching status, or urban/ rural location. Full patient, surgeon, and hospital demographics from the univariate analysis are seen in Table 1.

Multivariable logistic regression was performed to identify variables predictive of use of laparoscopy for rectal cancer (Table 2). The odds of receiving laparoscopic surgery have steadily improved over the years. Younger patients (<50 years old) (OR 1.49, 95% CI [1.03, 2.17], $p = 0.036$) and patients with minor (OR 2.13, 95% CI (1.45, 3.12), $p < 0.0001$) or moderate illness severity (OR 1.582, 95% CI [1.08, 2.31], $p < 0.0174$) were associated with higher odds of receiving a laparoscopic resection. While colorectal surgeons were more likely to approach a case laparoscopically than general surgeons, this association was not statistically significant after adjusting other covariates in the multivariable logistic analysis (OR 1.082, 95% CI [0.92, 1.27], $p < 0.3363$). Higher volume surgeons were more likely to use laparoscopy than low volume surgeons (OR=3.72, 95% CI: [2.64, 5.25], $p < 0.0001$). Teaching hospitals (OR=0.842, 95% CI [0.710, 0.997], $p = 0.0463$) and hospitals in the Midwest region (OR=0.69, 95% CI [0.54, 0.89, $p = 0.0044$) were less likely to use laparoscopy. Gender, insurance status, and hospital size did not

independently impact use of laparoscopy for rectal cancer receiving laparoscopic surgery in the multivariable regression model ($p > 0.05$).

Discussion

This is a turbulent time for laparoscopic surgery for rectal cancer. Early reports showed safety and efficacy of laparoscopy for curative rectal cancer resection, with equivalent oncologic endpoints (20, 29–35); controlled trials then affirmed similar 3-year overall survival, disease-free survival, and local recurrence compared to open surgery (16, 21–25). The adoption of minimally invasive approaches for rectal cancer resection continued to lag behind colon cancer (36). Then, recent reports of non-inferiority of laparoscopic resection compared with open resection for pathologic outcomes were published, concluding there sufficient evidence for the routine use of laparoscopic surgery (26, 27). Concurrently, there are national movements to improve outcomes and adherence to evidence-based guidelines through checklists, multidisciplinary tumor boards, and accredited centers of excellence (37–39). With these activities, defining the utilization and predictors of laparoscopy are warranted. Our goal was to evaluate the current utilization and identify factors impacting use of laparoscopic surgery for rectal cancer. We found use of laparoscopy increased during the study period, from 37.6% to 55.3%. From our results, there were identifiable patient, surgeon, and hospital factors that independently impacted likelihood of receiving a laparoscopic resection for rectal cancer. With these factors identified, surgeons can proactively work to safely increase laparoscopic approaches and surgical quality for rectal cancer patients.

Our study is a unique addition to the literature as no prior study has looked at the individual variables that are independently associated with use of a laparoscopic approach to curative rectal cancer resection. However, aspects of our results agree with previously published studies for improving outcomes in general for rectal cancer resection. A greater likelihood of laparoscopy in younger, less comorbid patients was found, which is an expected results; these factors have been widely seen in studies for colorectal cancer and described as a predictor of laparoscopy in colon cancer, but not previously for rectal cancer (40–42). In our study, surgeon specialty was an important predictive factor of laparoscopy, with colorectal surgeons 20% more likely to approach rectal cancer laparoscopically than general surgeons. While not focused on laparoscopy, prior studies have demonstrated the importance of surgeon specialization on outcomes, with colorectal surgeons and surgical oncologists having higher rates of restorative surgery [than colostomy formation] (43, 44) and improved overall survival (44–47). We also found geographic region was a significant predictor of use (and non-use) of laparoscopy, with the Midwest having the lowest rates. While not dedicated to laparoscopy, Monson et al. did find significant variation over 5-years study from the National Cancer Data Base in adherence to evidence-based rectal cancer guidelines across geographic regions (48). This variation in regional outcomes supports the development of rectal cancer centers of excellence in the US, where standardization could improve outcomes.

Our strongest predictor of laparoscopy for rectal cancer was surgeon volume. No previous study has looked at surgeon volume specifically related to laparoscopic use.

However, prior studies have shown the importance of volume on rectal cancer outcomes and surgical quality. Schrag et al reported that surgeon volume was the most important predictor of long-term survival, and remained an important predictor even after adjustment for hospital volume (49). Sphincter preservation has been reported as a surrogate for quality. Paquette et al found the most important predictor for sphincter preservation was high procedural volume (OR 1.55; 95% CI 1.33-1.79; $P < .001$) (50–52). Riccardi et al found 38.8% of surgeons in the US performed only nonrestorative procedures for rectal cancer; outcomes for these surgeons showed significantly higher mortality and longer length of stay compared those who performed both restorative and nonrestorative procedures (53). In reviewing a state-wide database over 5 years, Baek et al found only 8% ($n = 24$) of rectal cancer resections cases were performed at high-volume hospitals, however, there was significantly lower mortality and increased sphincter preservation in these higher-volume centers (50). The association between high-volume surgeons/ centers and improved outcomes supports referral to high-volume centers of excellence. (54).

Development of rectal cancer centers of excellence could integrate all of the factors that impact outcomes. Success has been proven in international models that regionalized care, standardized teaching and surgical techniques. The Norwegian Rectal Cancer Project increased the rate of total mesorectal excision, proportion of patients undergoing resection at high volume hospitals, increased rates of neoadjuvant therapy, reduced local recurrence, and increased survival for rectal cancer nationwide (55, 56). Similar improvements were seen with the Danish and Swedish National Rectal Cancer Registries,

where care was centralized, local recurrence was reduced, and cancer related survival increased (57, 58, 58). The progression of regionalized centers of excellence and the National Accreditation Program for Rectal Cancer could be a potential avenue to improve overall outcomes and safety expand utilization of laparoscopy for rectal cancer in the US (59).

We recognize the limitations of this study. The largest limitation was the retrospective study design, which has inherent limitations. We also used a national inpatient administrative data source, which has the potential for selection biases and coding errors. In this large sample size, we would not expect these to make a significant impact on our results or conclusions. Further, the sample size provided by the national inpatient data source was necessary to have the power to find significant differences across approaches and determine the predictive models. In the model, we included surgeon volume as a candidate predictor, but not hospital volume, under the assumption that surgeon volume is correlated with hospital volume and does not need to be an additional variable. However, it is possible that hospital volume could also be a significant factor. Future work will examine the impact of this variable.

In conclusion, we found the use of laparoscopy for rectal cancer has steadily increased over the years examined. Patient, provider, and regional variables exist, with hospital status, geographic location, and colorectal specialization impacting the likelihood receiving laparoscopic rectal cancer surgery. However, surgeon volume had the greatest influence. These results emphasize the importance of training and surgeon specific

outcomes to increase utilization, surgical quality, and improve patient recovery in appropriate cases.

Acknowledgement: The authors acknowledge the Medtronic Minimally Invasive Therapies Group for access to the data source and assistance with statistical modeling.

Disclosures: Drs. Keller and Senagore have no relevant disclosures. Ms. Qiu is employed by Medtronic, which gave access to the data source and assistance with statistical analysis.

Table Legend

Table 1: Patient and Hospital Demographics for Laparoscopic and Open Rectal Cancer

Resection

Table 2: Multivariable Logistic Regression Model for Variables Predictive of Laparoscopy in Rectal Cancer

References

1. Senagore AJ. Adoption of Laparoscopic Colorectal Surgery: It Was Quite a Journey. *Clin Colon Rectal Surg.* 2015;28:131-134.
2. Carmichael JC, Masoomi H, Mills S, Stamos MJ, Nguyen NT. Utilization of laparoscopy in colorectal surgery for cancer at academic medical centers: does site of surgery affect rate of laparoscopy? *Am Surg.* 2011;77:1300-1304.
3. Nguyen NT, Nguyen B, Shih A, Smith B, Hohmann S. Use of laparoscopy in general surgical operations at academic centers. *Surg Obes Relat Dis.* 2013;9:15-20.
4. Row D, Weiser MR. An update on laparoscopic resection for rectal cancer. *Cancer Control.* 2010;17:16-24.
5. Young M, Pigazzi A. Total mesorectal excision: open, laparoscopic or robotic. *Recent Results Cancer Res.* 2014;203:47-55.
6. Son GM, Kim JG, Lee JC et al. Multidimensional analysis of the learning curve for laparoscopic rectal cancer surgery. *J Laparoendosc Adv Surg Tech A.* 2010;20:609-617.
7. Li GX, Yan HT, Yu J, Lei ST, Xue Q, Cheng X. [Learning curve of laparoscopic resection for rectal cancer]. *Nan Fang Yi Ke Da Xue Xue Bao.* 2006;26:535-538.
8. Liang JW, Zhang XM, Zhou ZX, Wang Z, Bi JJ. [Learning curve of laparoscopic-assisted surgery for rectal cancer]. *Zhonghua Yi Xue Za Zhi.* 2011;91:1698-1701.
9. Lujan J, Gonzalez A, Abrisqueta J et al. The learning curve of laparoscopic treatment of rectal cancer does not increase morbidity. *Cir Esp.* 2014;92:485-490.
10. Nandakumar G, Fleshman JW. Laparoscopy for rectal cancer. *Surg Oncol Clin N Am.* 2010;19:793-802.
11. Lacy AM, Garcia-Valdecasas JC, Pique JM et al. Short-term outcome analysis of a randomized study comparing laparoscopic vs open colectomy for colon cancer. *Surg Endosc.* 1995;9:1101-1105.
12. Lacy AM, Garcia-Valdecasas JC, Delgado S et al. Laparoscopy-assisted colectomy versus open colectomy for treatment of non-metastatic colon cancer: a randomised trial. *Lancet.* 2002;359:2224-2229.
13. Lacy AM, Delgado S, Castells A et al. The long-term results of a randomized clinical trial of laparoscopy-assisted versus open surgery for colon cancer. *Ann Surg.* 2008;248:1-7.
14. Guillou PJ, Quirke P, Thorpe H et al. Short-term endpoints of conventional versus laparoscopic-assisted surgery in patients with colorectal cancer (MRC CLASICC trial): multicentre, randomised controlled trial. *Lancet.* 2005;365:1718-1726.
15. Bonjer HJ, Hop WC, Nelson H et al. Laparoscopically assisted vs open colectomy for colon cancer: a meta-analysis. *Arch Surg.* 2007;142:298-303.
16. Jayne DG, Guillou PJ, Thorpe H et al. Randomized trial of laparoscopic-assisted resection of colorectal carcinoma: 3-year results of the UK MRC CLASICC Trial Group. *J Clin Oncol.* 2007;25:3061-3068.
17. Buunen M, Veldkamp R, Hop WC et al. Survival after laparoscopic surgery versus open surgery for colon cancer: long-term outcome of a randomised clinical trial. *Lancet Oncol.* 2009;10:44-52.
18. Veldkamp R, Kuhry E, Hop WC et al. Laparoscopic surgery versus open surgery for colon cancer: short-term outcomes of a randomised trial. *Lancet Oncol.* 2005;6:477-484.

19. COST Trial Study Group. A comparison of laparoscopically assisted and open colectomy for colon cancer. *N Engl J Med.* 2004;350:2050-2059.
20. Lujan J, Valero G, Hernandez Q, Sanchez A, Frutos MD, Parrilla P. Randomized clinical trial comparing laparoscopic and open surgery in patients with rectal cancer. *Br J Surg.* 2009;96:982-989.
21. Jeong SY, Park JW, Nam BH et al. Open versus laparoscopic surgery for mid-rectal or low-rectal cancer after neoadjuvant chemoradiotherapy (COREAN trial): survival outcomes of an open-label, non-inferiority, randomised controlled trial. *Lancet Oncol.* 2014;15:767-774.
22. Kang SB, Park JW, Jeong SY et al. Open versus laparoscopic surgery for mid or low rectal cancer after neoadjuvant chemoradiotherapy (COREAN trial): short-term outcomes of an open-label randomised controlled trial. *Lancet Oncol.* 2010;11:637-645.
23. Bonjer HJ, Deijen CL, Abis GA et al. A randomized trial of laparoscopic versus open surgery for rectal cancer. *N Engl J Med.* 2015;372:1324-1332.
24. Green BL, Marshall HC, Collinson F et al. Long-term follow-up of the Medical Research Council CLASICC trial of conventional versus laparoscopically assisted resection in colorectal cancer. *Br J Surg.* 2013;100:75-82.
25. Jayne DG, Thorpe HC, Copeland J, Quirke P, Brown JM, Guillou PJ. Five-year follow-up of the Medical Research Council CLASICC trial of laparoscopically assisted versus open surgery for colorectal cancer. *Br J Surg.* 2010;97:1638-1645.
26. Fleshman J, Branda M, Sargent DJ et al. Effect of Laparoscopic-Assisted Resection vs Open Resection of Stage II or III Rectal Cancer on Pathologic Outcomes: The ACOSOG Z6051 Randomized Clinical Trial. *JAMA.* 2015;314:1346-1355.
27. Stevenson AR, Solomon MJ, Lumley JW et al. Effect of Laparoscopic-Assisted Resection vs Open Resection on Pathological Outcomes in Rectal Cancer: The ALaCaRT Randomized Clinical Trial. *JAMA.* 2015;314:1356-1363.
28. All Patient Refined Diagnostic Related Groups Methodology Overview. v20.0. 3M Health Information Systems. Available Online at: <<http://www.hcup-us.ahrq.gov/db/nation/nis/APR-DRGsV20MethodologyOverviewandBibliography.pdf>>. Last accessed June 2015.
29. Yamamoto S, Inomata M, Katayama H et al. Short-term surgical outcomes from a randomized controlled trial to evaluate laparoscopic and open D3 dissection for stage II/III colon cancer: Japan Clinical Oncology Group Study JCOG 0404. *Ann Surg.* 2014;260:23-30.
30. Rullier E, Sa Cunha A, Couderc P, Rullier A, Gontier R, Saric J. Laparoscopic intersphincteric resection with colooplasty and coloanal anastomosis for mid and low rectal cancer. *Br J Surg.* 2003;90:445-451.
31. Morino M, Parini U, Giraudo G, Salval M, Brachet Contul R, Garrone C. Laparoscopic total mesorectal excision: a consecutive series of 100 patients. *Ann Surg.* 2003;237:335-342.
32. Anthuber M, Fuerst A, Elser F, Berger R, Jauch KW. Outcome of laparoscopic surgery for rectal cancer in 101 patients. *Dis Colon Rectum.* 2003;46:1047-1053.
33. Feliciotti F, Guerrieri M, Paganini AM et al. Long-term results of laparoscopic versus open resections for rectal cancer for 124 unselected patients. *Surg Endosc.* 2003;17:1530-1535.

34. Dulucq JL, Wintringer P, Stabilini C, Mahajna A. Laparoscopic rectal resection with anal sphincter preservation for rectal cancer: long-term outcome. *Surg Endosc.* 2005;19:1468-1474.
35. Aziz O, Constantinides V, Tekkis PP et al. Laparoscopic versus open surgery for rectal cancer: a meta-analysis. *Ann Surg Oncol.* 2006;13:413-424.
36. Fleshman J. Current Status of Minimally Invasive Surgery for Rectal Cancer. *J Gastrointest Surg.* 2016;20:1056-1064.
37. Glasgow SC, Morris AM, Baxter NN et al. Development of The American Society of Colon and Rectal Surgeons' Rectal Cancer Surgery Checklist. *Dis Colon Rectum.* 2016;59:601-606.
38. Fleshman JW. Multidisciplinary treatment of rectal cancer: the way of the future. *JAMA Surg.* 2013;148:778.
39. Dietz DW, Consortium, for Optimizing Surgical Treatment of Rectal Cancer (OSTRiCh). Multidisciplinary management of rectal cancer: the OSTRICH. *J Gastrointest Surg.* 2013;17:1863-1868.
40. Kemp JA, Finlayson SR. Outcomes of laparoscopic and open colectomy: a national population-based comparison. *Surg Innov.* 2008;15:277-283.
41. Huang MJ, Liang JL, Wang H, Kang L, Deng YH, Wang JP. Laparoscopic-assisted versus open surgery for rectal cancer: a meta-analysis of randomized controlled trials on oncologic adequacy of resection and long-term oncologic outcomes. *Int J Colorectal Dis.* 2011;26:415-421.
42. Keller DS, Parikh N, Senagore AJ. Predicting opportunities to increase utilization of laparoscopy for colon cancer. *Surg Endosc.* 2016
43. Ricciardi R, Roberts PL, Read TE, Baxter NN, Marcello PW, Schoetz DJ. Presence of specialty surgeons reduces the likelihood of colostomy after proctectomy for rectal cancer. *Dis Colon Rectum.* 2011;54:207-213.
44. Borowski DW, Kelly SB, Bradburn DM et al. Impact of surgeon volume and specialization on short-term outcomes in colorectal cancer surgery. *Br J Surg.* 2007;94:880-889.
45. Barbas AS, Turley RS, Mantyh CR, Migaly J. Effect of surgeon specialization on long-term survival following colon cancer resection at an NCI-designated cancer center. *J Surg Oncol.* 2012;106:219-223.
46. Hohenberger W, Merkel S, Hermanek P. Volume and outcome in rectal cancer surgery: the importance of quality management. *Int J Colorectal Dis.* 2013;28:197-206.
47. Oliphant R, Nicholson GA, Horgan PG et al. Contribution of surgical specialization to improved colorectal cancer survival. *Br J Surg.* 2013;100:1388-1395.
48. Monson JR, Probst CP, Wexner SD et al. Failure of evidence-based cancer care in the United States: the association between rectal cancer treatment, cancer center volume, and geography. *Ann Surg.* 2014;260:625-31; discussion 631.
49. Schrag D, Panageas KS, Riedel E et al. Hospital and surgeon procedure volume as predictors of outcome following rectal cancer resection. *Ann Surg.* 2002;236:583-592.
50. Baek JH, Alrubaie A, Guzman EA et al. The association of hospital volume with rectal cancer surgery outcomes. *Int J Colorectal Dis.* 2013;28:191-196.
51. Paquette IM, Kemp JA, Finlayson SR. Patient and hospital factors associated with

- use of sphincter-sparing surgery for rectal cancer. *Dis Colon Rectum*. 2010;53:115-120.
52. Ricciardi R, Virnig BA, Madoff RD, Rothenberger DA, Baxter NN. The status of radical proctectomy and sphincter-sparing surgery in the United States. *Dis Colon Rectum*. 2007;50:1119-27; discussion 1126.
 53. Ricciardi R, Roberts PL, Read TE, Baxter NN, Marcello PW, Schoetz DJ. Who performs proctectomy for rectal cancer in the United States. *Dis Colon Rectum*. 2011;54:1210-1215.
 54. Aquina CT, Probst CP, Becerra AZ et al. High volume improves outcomes: The argument for centralization of rectal cancer surgery. *Surgery*. 2016;159:736-748.
 55. Wibe A, Moller B, Norstein J et al. A national strategic change in treatment policy for rectal cancer--implementation of total mesorectal excision as routine treatment in Norway. A national audit. *Dis Colon Rectum*. 2002;45:857-866.
 56. Guren MG, Kørner H, Pfeffer F et al. Nationwide improvement of rectal cancer treatment outcomes in Norway, 1993-2010. *Acta Oncol*. 2015;54:1714-1722.
 57. Martling AL, Holm T, Rutqvist LE, Moran BJ, Heald RJ, Cedemark B. Effect of a surgical training programme on outcome of rectal cancer in the County of Stockholm. Stockholm Colorectal Cancer Study Group, Basingstoke Bowel Cancer Research Project. *Lancet*. 2000;356:93-96.
 58. Khani MH, Smedh K. Centralization of rectal cancer surgery improves long-term survival. *Colorectal Dis*. 2010;12:874-879.
 59. American College of Surgeons, Quality Programs. National Accreditation Program for Rectal Cancer. Available online at: <https://www.facs.org/quality-programs/cancer/naprc>. Last assessed March 17, 2017.

Appendix 1: Rectal Procedures and Stoma Codes
46.04 Resection of exteriorized segment of large intestine
48.40 Pull-through resection of rectum, not otherwise specified
48.42 Laparoscopic pull-through resection of rectum
48.43 Open pull-through resection of rectum
48.50 Abdominoperineal resection of the rectum, not otherwise specified
48.51 Laparoscopic abdominoperineal resection of the rectum
48.52 Open abdominoperineal resection of the rectum
48.49 Other pull-through resection of rectum
48.59 Other abdominoperineal resection of the rectum
48.69 Other resection of rectum, (Partial proctectomy, Rectal resection NOS)
48.62 Anterior resection of rectum with synchronous colostomy
48.63 Other anterior resection of rectum
48.64 Posterior resection of rectum
48.65 Duhamel abdominoperineal pull-through
17.36 Laparoscopic Sigmoidectomy

Patient and Hospital Demographics	MIS		OPEN		p-value
	<i>n=1,464</i>		<i>n=1,872</i>		
Patient characteristics	<i>N</i>	<i>Col. %</i>	<i>N</i>	<i>Col. %</i>	
Mean Age. Years (SD)	60.7 ± 11.9		62.8 ± 12.1		<0.0001
Age category					
Less than 50 years	298	20.36	295	15.76	<0.0001
51-60 years	448	30.60	553	29.54	
61-70 years	410	28.01	499	26.66	
71-80 years	221	15.10	379	20.25	

More than 80 years	87	5.94	146	7.80	
Gender					
Female	550	37.57	673	35.95	0.336
Male	914	62.43	1199	64.05	
Race					
Caucasian	1100	75.14	1275	68.11	0.0001
African American	89	6.08	146	7.80	
Hispanic	11	0.75	17	0.91	
Other	264	18.03	434	23.18	
Insurance Type					
Medicaid	90	6.15	157	8.39	<0.0001
Managed Care	707	48.29	750	40.06	
Other	117	7.99	151	8.07	
Medicare	550	37.57	814	43.48	
APR severity of illness					
Minor	619	42.28	596	31.84	<0.0001
Moderate	626	42.76	840	44.87	
Major	176	12.02	331	17.68	
Extreme	43	2.94	105	5.61	
Year of Surgery					
2015 (first 3 quarters)	120	8.20	97	5.18	<0.0001
2014	298	20.36	344	18.38	
2013	386	26.37	403	21.53	
2012	217	14.82	326	17.41	
2011	227	15.51	376	20.09	
2010	216	14.75	326	17.41	
Surgeon characteristics					
Physician specialty					
Colorectal surgeon	604	41.31	685	36.65	0.023
Other surgeon	101	6.91	142	7.60	
General surgeon	757	51.78	1042	55.75	
Physician Volume					
High (20 +/-year)	138	9.44	56	3.00	<0.0001
Medium (10-20/year)	153	10.47	165	8.83	
Low (< 10 cases/year)	1171	80.10	1648	88.18	
Hospital characteristics					
Hospital Region					
Midwest	242	16.53	368	19.66	0.018
Northeast	327	22.34	350	18.70	
South	644	43.99	817	43.64	
West	251	17.14	337	18.00	
Teaching Hospital					
Non-Teaching Hospital	743	50.75	941	50.27	0.781
Teaching Hospital	721	49.25	931	49.73	

Bed Size					
500+ beds	651	44.47	781	41.72	0.242
250-500 beds	583	39.82	795	42.47	
<250 beds	230	15.71	296	15.81	
Urban vs rural					
Rural	113	7.72	159	8.49	0.417
Urban	1351	92.28	1713	91.51	

Table 1: Patient and Hospital Demographics for Laparoscopic and Open Rectal Cancer Resection

Variable (Reference Field)	Adjusted OR	95% CI of OR	p-value
Year of Surgery (2010)			
2015 (first 3 quarters)	1.856	(1.33, 2.58)	0.0002
2014	1.293	(1.02, 1.65)	0.0377
2013	1.435	(1.14, 1.81)	0.0022
2012	1.035	(0.80, 1.33)	0.7892
2011	0.918	(0.72, 1.17)	0.4947
Age category (>80y)			
Less than 50 years	1.493	(1.03, 2.17)	0.036
51-60 years	1.179	(0.83, 1.69)	0.3667
61-70 years	1.287	(0.94, 1.77)	0.1195
71-80 years	0.978	(0.71, 1.35)	0.8926
Gender (Male)- Female	1.02	(0.88, 1.18)	0.7922
Race (Caucasian)			
African American	0.772	(0.58, 1.03)	0.0766
Hispanic	0.979	(0.45, 2.15)	0.9574
Other	0.618	(0.51, 0.75)	<0.0001
Insurance Type (Medicare)			
Medicaid	0.745	(0.54, 1.04)	0.0791
Managed Care	1.09	(0.88, 1.36)	0.4366
Other	1.012	(0.74, 1.39)	0.9431
APR illness severity (Extreme)			
Minor	2.129	(1.45, 3.12)	0.0001
Moderate	1.582	(1.08, 2.31)	0.0174
Major	1.239	(0.83, 1.86)	0.3019
Surgeon specialty (General)			

Colon/rectal surgeon	1.082	(0.92, 1.27)	0.3363
Other surgeon	1.071	(0.81, 1.42)	0.634
Physician volume (Low)			
High (20 +/year)	3.724	(2.64, 5.25)	<0.0001
Medium (10-20/year)	1.2	(0.94, 1.54)	0.1524
Hospital Region (West)			
Midwest	0.694	(0.54, 0.89)	0.0044
Northeast	1.018	(0.79, 1.31)	0.8886
South	0.881	(0.71, 1.09)	0.2424
Teaching Hospital (Teaching)			
Non-Teaching Hospital	1.188	(1.00, 1.41)	0.0463
Bed Size (<250 beds)			
500+ beds	1.026	(0.81, 1.30)	0.8344
250-500 beds	0.907	(0.73, 1.13)	0.381
Urban vs rural (Urban)			
Rural	0.921	(0.69, 1.22)	0.5669

Table 2: Multivariate Logistic Regression Model for Variables Predictive of Laparoscopy in Rectal Cancer