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Colorectal Surgery Fellowship improves in-hospital mortality after colectomy and proctectomy irrespective of hospital and surgeon volume

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Abstract

Background: General surgery residents are increasingly pursuing subspecialty training in colorectal (CR) surgery. However, the majority of operations performed by CR surgeons are also performed by general surgeons. This study aimed to assess in-hospital mortality stratified by CR training status after adjusting for surgeon and hospital volume.

Methods: The Statewide Planning and Research Cooperative system database was used to identify all patients who underwent colectomy/proctectomy from January 1, 2000 to December 31, 2014 in the State of New York. Operations performed by board-certified CR surgeons were identified. The relationships between CR board certification and in-hospital mortality, in-hospital complications, length of stay, and ostomy were assessed using multivariate regression models.

Results: 270,684 patients underwent colectomy/proctectomy over the study period. 72,279 (26.7%) of operations were performed by CR surgeons. Without adjusting for hospital and surgeon volume, in-hospital mortality was lower for those undergoing colectomy/proctectomy by a CR

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surgeon (OR 0.49, CI 0.44–0.54, $p<0.01$). After controlling for hospital and surgeon volume, the odds of inpatient mortality after colectomy/proctectomy for those operated on by CR surgeons weakened to 0.76 (CI 0.68–0.86, $p<0.01$). Hospital and surgeon volume accounted for 53% of the reduction in in-hospital mortality when CR surgeons performed colectomy/proctectomy. Patients who underwent surgery by a CR surgeon had a shorter inpatient stay (0.8 days, $p<0.01$) and a decreased chance of colostomy (OR 0.86, CI 0.78–0.95, $p<0.01$).

Conclusions: For patients undergoing colectomy/proctectomy, in-hospital mortality decreased when the operation was performed by a CR surgeon even after accounting for hospital and surgeon volume.

Keywords

colorectal surgery fellowship; surgeon volume

INTRODUCTION:

Colorectal (CR) surgery fellowship training has become increasingly popular among general surgery residents. While there has been a long history of proctology and CR surgery in the United States (The American Board of Proctology was incorporated in 1935 and it was accepted as a primary specialty board by the American Board of Surgery in 1949), the last twenty years have shown exponential growth in the field. In 2016, there were 93 positions distributed between 54 programs.¹ This has increased from 80 fellowship positions in 2010. Currently, the American Board of Colon and Rectal Surgery has 1,801 members listed as active in the United States. However, 74% of CR surgeons perform some aspect of general surgery in their practice. Additionally, the majority of operations performed by CR surgeons are also performed by general surgeons. In short, there is considerable overlap between the specialties.² Because of this, there has been significant debate over whether there is any benefit to CR surgery subspecialty training.

Some have argued that the only benefit of CR surgery training is the additive volume of surgery performed during fellowship. Proponents of this belief point out that there has been a repeated and well-documented relationship between hospital and surgeon volume and surgical outcomes;³ however, whether there is additional benefit of subspecialty training outside the volume-outcome relationship is still not clear. The aim of this study was to assess in-hospital mortality, inpatient complications, length of stay, and ostomy creation stratified by CR surgery training status after adjusting for surgeon and hospital volume.

METHODS:

All data was obtained from the Statewide Planning and Research Cooperative System (SPARCS) database from January 1, 2000 to December 31, 2014. SPARCS is a comprehensive, all-payer database established in 1979 by the state of New York to collect information on inpatient and outpatient care in that state. It includes patient level data, diagnoses, treatments, services, charge information, and discharge status. This database was queried to identify all patients who underwent colectomy and proctectomy during the study period. Colectomy and proctectomy were identified using the ICD-9 codes identified in

Table 1. Exclusion criteria included age younger than 18 years and an operation performed for trauma. Laparoscopic surgeries were identified using ICD-9 codes specific for laparoscopic colectomy and proctectomy; additionally, they were identified using the modifier 55.8, 55.81, 55.82, 55.83, and 55.89. Colostomy and ileostomy were identified via ICD-9 codes including: colostomy, 46.10, 46.11, 46.13, 48.50, 48.51, 48.52, 48.59, and 48.62, and ileostomy 46.01, 46.20, 46.21, 46.22, and 46.23. Complications were also assessed using ICD-9 coding and included: shock, hemorrhage, wound disruption, post-operative infection, respiratory complications, digestive complications, urinary complications, foreign body left intra-operatively, reoperation, and other. Urgency of the operation cannot be assessed reliably using the SPARCS database.

Surgeons were identified as being CR surgery board-certified using data obtained from the American Board of Colon and Rectal Surgery (ABCRS) database.⁴ This provided a list of all board-certified CR surgeons registered within the state of New York in 2016. Patients were subsequently identified as having an operation performed by a surgeon who had undergone CR sub-specialty training and were CR board-certified by cross-referencing state license numbers from the ABCRS to those found in the SPARCS dataset. All other surgeons were described as general surgeons (including any surgeon who was not CR boarded and performed a colectomy or proctectomy during the study period regardless of other sub-specialty training status or board certification). To ensure that CR surgeons were not missed via these methods, all general surgeons who performed 38 or more colectomies or proctectomies during any one-year period from 2000–2014 were audited. The use of 38 colectomies/proctectomies was determined as this was the average number of colectomies/proctectomies for CR surgeons over the study period. This group of high volume “general surgeons” numbered 153 surgeons. Of this group, 22 (14%) were discovered to be board-certified CR surgeons who were registered in other states in 2016 or for some reason not listed under the ABCRS database. These surgeons were included in the CR surgery group.

Statistical analysis was performed using Stata 13 IC (STATA Corp., College Station, Texas). Univariate analysis was performed using the student's *t* test for continuous variables and the chi square test for categorical variables. The relationship between CR surgery board certification and in-hospital mortality, in-hospital complications, and ostomy creation was assessed using multivariate logistic regression clustered on hospital, adjusting for patient comorbidities and surgical indication/characteristics. Length of stay was assessed using a multivariate linear regression.

Hospital and surgeon volume of colectomies and proctectomies performed annually for the year the patient underwent surgery were calculated using the SPARCS dataset. Volume was also measured, indirectly, by looking at the “operative velocity”, or the average amount of time between colectomies/proctectomies by the same surgeon. The effect of surgeon and hospital volume on CR board certification was assessed using multiple multivariate logistic regression model comparisons. Statistical significance was defined at a $p < 0.05$. To determine the effect of surgeon/hospital volume on the relationship between CR certification and mortality, the relative attenuation of odds ratio was used: $(OR_C - OR_{CV}) / (OR_C - 1)$, where OR_C is the odds ratio for mortality with a CR surgeon without adjusting for surgeon/hospital

volume and OR_{CV} is the odds ratio for mortality for CR surgeons after adjusting for surgeon/hospital volume.⁵

Three sensitivity analyses were performed to confirm our findings in regards to in-hospital mortality. The first was performed using only patients who underwent surgery for malignancy. This assumedly excluded most patients who underwent surgery on an urgent basis and allowed us to roughly control for urgent basis of surgery. The second two sensitivity analyses were performed assessing in-hospital mortality in the colectomy and proctectomy populations, separately.

RESULTS:

Over the study period, 270,684 patients over the age of 18 were identified who underwent colectomy or proctectomy for reasons other than trauma. These operations were performed by 8,217 general surgeons and 196 CR board-certified surgeons. 22,365 (51.3%) of proctectomies were performed by general surgeons and 21,235 (48.7%) proctectomies by CR surgeons. 178,809 (77.0%) of colectomies were performed by general surgeons and 53,401 (23.0%) by CR surgeons. Total 72,279 (26.7%) of operations were performed by a CR surgeon. Patients who underwent a procedure by a CR surgeon were more likely to be younger (62.3 versus 64.5 years, $p<0.01$), more likely to be male (46.7% versus 45.0, $p<0.01$), and more likely to be of Caucasian race (80.1% versus 74.8%, $p<0.01$). See Table 2. Patients of CR surgeons were slightly healthier with only 32.7% having a Charlson Comorbidity Index over 3 (compared to 37.0% of patients operated on by general surgeons). Additionally, patients who underwent surgery with a CR trained surgeon were more likely to have had a laparoscopic (27.9% versus 13.4%; $p<0.01$) or robotic (3.8% versus 0.4%, $p<0.01$) operation. On the whole, patients who underwent surgery with a CR surgeon were more often younger, healthier, male and Caucasian than their general surgery counterparts. They were also more likely to have undergone minimally invasive surgery.

The indications for surgery and type of operation performed differed significantly between those performed by a CR surgeon and those performed by general surgeons. 46.5% of cases performed by those with CR board-certification were done out of concern for malignancy compared with only 38.4% of cases performed by general surgeons ($p<0.01$). In addition, CR surgeons were more likely to operate for diverticulitis (5.7%), inflammatory bowel disease (8.3%), and rectal prolapse (4.1%) than general surgeons; whereas general surgeons operated more for perforation (5.7%), ischemia (5.4%), and hemorrhage (4.2%) than their CR surgery counterparts. The type of operation differed by training status as well. 70.6% of the cases performed by CR surgeons were colectomies and 29.4% were proctectomies; on the other hand, of the cases identified as performed by general surgeons, 88.7% were colectomies and 11.3% were proctectomies ($p<0.01$).

CR surgeons had higher volumes of colectomies and proctectomies annually (38 cases per year for CR surgeons versus 7 for general surgeons, $p<0.01$). The “operative velocity”, or the average time between colectomy/proctectomy for a CR surgeon was 0.3 months compared to 1.7 months for a general surgeon ($p<0.01$). Examining all surgeons who performed at least one proctectomy over the study period by “surgeon year” demonstrated

that 34% of general surgeon years included no proctectomies in one year, 20.7% included one proctectomy a year, and 12.7% had two a year. This is compared to CR surgeon years of which only 1% had no proctectomies in a year, 1.9% had one a year, and 2% had two a year. Operations performed by CR surgeon were more often performed at academic hospitals (47.3% versus 28.9%, $p<0.01$). The average hospital volume of colectomies and proctectomies per year for those patients who underwent surgery by a CR surgeon was 256 versus 179 for those operated on by general surgeons ($p<0.01$).

Using a multivariate model adjusting for Charlson co-morbidity index, age, sex, race, operative indication, and laparoscopic procedure demonstrated that patients operated on by a CR surgeon had a decreased incidence of inpatient mortality (even after adjusting for surgeon and hospital volume). Without adjusting for surgeon and hospital volume, in-hospital mortality was significantly lower for those undergoing colectomy/proctectomy by a CR surgeon (OR 0.49, CI 0.44–0.54, $p<0.01$). After controlling for hospital and surgeon volume, the odds of inpatient mortality after colectomy/proctectomy for those operated on by CR surgeon weakened to 0.76 (CI 0.68–0.86, $p<0.01$). See Table 3. Therefore, using the attenuation of odds methodology, hospital and surgeon volume accounted for 53% of the reduction in in-hospital mortality when those with CR board-certification perform a colectomy or proctectomy. While hospital and surgeon volume accounted for more than half of the mortality benefit, there was still additional benefit from CR sub-specialty training and board certification (not explained by volume).

Patients of CR surgeons saw benefits other than mortality. In an unadjusted analysis: patients of general surgeons stayed 12.6 days in the hospital versus 8.6 for CR surgeons ($p<0.01$). In a multivariate, linear regression model (adjusting for surgeon and hospital volume among other factors) length of stay was 0.8 days shorter for those who underwent surgery by CR surgeon (CI –1.20–0.34, $p<0.01$). In an unadjusted analysis assessing inpatient complications, patients were less likely to have complications after surgery if operated on by CR surgeons (22.1% versus 26.1%, $p<0.01$). However, when a multivariate logistic regression model was performed accounting for surgeon and hospital volume, the benefit in complication occurrence disappeared (OR 1.06, CI 0.97–1.17, $p=0.19$). Both unadjusted and multivariate analyses showed no difference between CR surgeons and general surgeons for need for reoperation. Overall, patients of colorectal surgeons had decreased length of stay but a similar incidence of complications.

Of special interest to surgeons and patients alike was the incidence of stoma formation in patients who underwent colectomy and proctectomy. In an un-adjusted analysis, the incidence of all stomas (ileostomy and colostomy combined) was slightly less for CR surgeons (21.7% versus 23.2%, $p<0.01$). This difference was not maintained on a multivariate adjusted logistic regression adjusting for surgeon and hospital volume (OR 1.06, $p=0.32$, of having an ostomy for those operated on by CR surgeons). However, after separation of ileostomy and colostomy, patients of CR surgeons were less likely to have a colostomy (OR 0.86, CI 0.78–0.95, $p<0.01$). This difference was intensified when restricting the analysis to patients who had surgery for diverticulitis (13,004 patients): OR of 0.82 (CI 0.70–0.96, $p=0.02$) when adjusting for hospital and surgeon volume, and OR of 0.68 (0.57–0.81, $p<0.01$) when not adjusting for volume. For patients who had surgery for malignancy

(excluding abdominoperineal resections) there was a decreased risk of colostomy (OR 0.68, CI 0.59–0.78, $p<0.01$) that also attenuated after adjusting for surgeon and hospital volume (OR 0.91, CI 0.81–1.02, $p=0.11$). Overall, in regards to *all* ostomy formation, there was no difference between CR surgeons and general surgeons; however, CR surgeons had decreased formation of colostomy (particularly when operations were performed for diverticulitis).

In an effort to exclude most operations performed on an urgent basis, a sensitivity analysis was performed restricting the analysis to those patients who underwent procedures for malignancy. Restricting analysis to those patients with malignancy decreased the number of patients assessed from 279,684 to 109,906 patients. Despite this restriction, CR surgery board-certification still conferred a mortality benefit (OR 0.78, CI 0.67–0.92, $p<0.01$) when controlling for surgeon volume and hospital volume. Other sensitivity analyses, examining the odds of inpatient mortality in patients who had colectomy alone (OR=0.77 favoring CR surgeons, CI 0.69–0.88, $p<0.01$), or proctectomy alone (OR=0.65 favoring CR surgeons, CI 0.52–0.82, $p<0.01$) demonstrated similar benefits towards surgery performed by CR surgeons (even with adjustment for surgeon and hospital volume).

Finally, along with the national increase in number of CR surgery fellows, there was a corresponding increase in the number of board-certified CR surgeons practicing in NY state over the study period. The absolute number of CR surgeons in the state of NY increased by 68 surgeons over the study period. The proportion of colectomies and proctectomies being performed by these surgeons (in comparison to general surgeons) increased from 16.6% in 2000 to 40.1% by 2014 ($p<0.01$). See Table 5. Overall, the number of CR surgeons and the proportion of colectomies and proctectomies they were performing increased in the state of New York over the study period.

DISCUSSION:

In summary, patients whose operations were performed by CR surgeons had significantly lower odds of inpatient mortality compared to patients who had operations performed by general surgeons, even after accounting for surgeon and hospital volume. They also had decreased length of stay and decreased incidence of colostomy (again, even after accounting for hospital and surgeon volume). This suggests that CR surgery fellowship training and board-certification confers many benefits that are not fully accounted for by annual hospital and surgeon volume alone. In particular, the mortality benefit was maintained when restricting analysis to patients who had their operation performed for malignancy (which roughly removes patients who underwent procedures for an urgent concern).

Over the last twenty years, general surgery residents have increasingly pursued sub-specialty training. From 1993 to 2005, general surgery residents who chose to perform a fellowship increased from 67% to 77%.⁶ Currently, around 80% of general surgery residents pursue sub-specialty training.^{7, 8} This transition has had ramifications on the structure of general surgery residency, the variety of training paradigms available to residents, and to the types of surgeon available to patients. As the absolute number of CR surgeons has increased, the proportion of operations performed by CR surgeons compared to other surgeons has also increased. In a study looking at SEER Medicare data from 1992–2002, the proportion of CR

procedures performed by a CR surgeon increased from 12.2% to 23.0% over the study period with 30% of total anorectal procedures, 22% of proctectomies, 14% of ostomy related procedures, and 11.5% of colectomies performed by a CR surgeon over those ten years.⁹ Colorectal sub-specialty training has focused on providing fellows with experience in the preoperative, operative, and postoperative care for patients with colorectal cancer, diverticulitis, inflammatory bowel disease, anorectal disorders, and pelvic floor disorders. There is a focus on mastering complex laparoscopy and endoscopy. While most of the procedures entailed in the specialty can be performed by a general surgeon, our study indicates that the specialized focus of CR surgery fellowship provides benefits to patients. There have been numerous hypotheses as to what contributes to this benefit: volume of case exposure in fellowship, experiential learning in fellowship, existence in a specialized milieu, and focused academic attention to the field.

Part of the mortality benefit gleaned from operations performed by CR surgeons can be explained by the benefit of hospital and surgeon volume. Numerous studies have shown the benefit of specific surgeon volume and hospital volume on patient outcomes across a variety of procedures. Birkmeyer, in some of his early work, demonstrated that the absolute observed mortality at high volume hospitals for colectomy was 5.4% compared to 6.9% at low volume hospitals.³ It is believed that high hospital volume in a specific procedure goes hand in hand with access to certain hospital-based services such as intensive care, respiratory care, and specialized nursing that could potentially improve mortality rates. In regard to individual surgeon volume and its benefit on operative mortality, Hannan et al. showed that the observed mortality after colectomy fell from 4.8% for the lowest volume quartile of surgeons to 2.2% for the highest volume quartile of surgeons.¹⁰ This benefit has been explained as resulting from the experience and technical skill gained from repetition of a procedure. Our work clearly demonstrates that there is significant mortality benefit to both hospital and surgeon volume when undergoing a colectomy or proctectomy.

The idea that surgeon volume is beneficial to operative mortality is not surprising given the work that has been done regarding learning curve for CR operations. In almost every operation, there has been a documented and distinct improvement in patient outcomes after surgeon completion of a certain number of operations. Historically, for laparoscopic colectomy, a learning curve between 30 and 60 cases has been reported as necessary to achieve proficiency.¹¹ However, the learning curve is variable depending on which study is looked at and what outcome is chosen through which to measure proficiency: a multi-center pooled analysis of 4852 cases of laparoscopic colectomy from 19 surgeons in 7 institutions showed that the learning curve was 152 cases for conversion to open, 143 for complications, 96 for operating time, 87 for blood loss, and 103 for length of stay.¹²

Given the variable number of cases required to overcome different aspects of the learning curve for CR surgery, studies have examined whether general surgery trainees obtain adequate experience during residency to become proficient. In 2014, the average number of laparoscopic colon resections for a graduating general surgery resident was 21.6. In contrast, CR surgery fellows performed 81.9 laparoscopic colon resections over the course of their fellowship. Given the numbers needed to achieve proficiency, this makes it much more likely that a fellowship trained individual will have achieved proficiency prior to starting practice.

¹³ A qualitative study of CR fellowship graduates from 2004 to 2009 assessed their comfort level in performing laparoscopic colectomy. After graduating from general residency, prior to starting CR fellowship, only 16.4% felt comfortable performing a laparoscopic right colectomy and 9% felt comfortable with a laparoscopic left colectomy. By the end of CR surgery training, 79.6% were comfortable with a laparoscopic right colectomy and 100% were comfortable with a laparoscopic left colectomy.¹⁴ In the arena of laparoscopic colectomy, CR fellowship provides significant exposure and case volume ensuring comfort when performing laparoscopic procedures upon graduation. It also allows the opportunity for high volume practice that allows trainees to progress through the learning curve.

The literature clearly demonstrates the benefit of high volume surgeons regardless of sub-specialty training; however, recently there have been studies (in addition to our own) that demonstrate the benefit of sub-specialization after controlling for surgeon volume.¹⁵ Recent work examining the association between surgeon specialization and operative mortality shows a benefit to specialization controlled for surgeon volume. In this study, surgeon specialization was defined as surgeon procedure specific volume (for example, esophagectomy), divided by that surgeon's total operative volume. The study authors hypothesized that improved muscle memory/dexterity, improved understanding of medical devices, and decreased mental fatigue from switching tasks accounted for this benefit.¹⁶ Performing a sub-specialty fellowship often begets a career of sub-specialization so it can be assumed that the performance of a fellowship, in most cases, will result in a career dedicated to a focused scope of procedures. When looking at the benefit of fellowship training in and of itself, another study showed that there was significant mortality benefit after colectomy and gastrectomy if the operation had been performed by a CR surgeon or surgical oncologist while controlling for surgeon and hospital volume. The odds of death for a patient undergoing a gastrectomy by a surgical oncologist was 0.70 times less than those performed by a general surgeon. For those undergoing a colectomy by a CR surgeon, the odds of inpatient mortality was 0.45 times less than those whose operation was performed by a general surgeon.¹⁷ All of these previous studies corroborate the association we found between improved mortality for patients who underwent colectomies and proctectomies by a CR surgeon (even after controlling for hospital and surgeon annual volume).

There are many hypotheses as to what accounts for this benefit of sub-specialty training. As stated above, sub-specialization and focused practice in a select few operations may account for a portion of this benefit. Another advantage may be an intimate knowledge of the field in which these sub-specialized surgeons are operating. By existing in the specialized milieu of CR surgery, CR surgeons may be more exposed to new and beneficial advances in the field such as enhanced recovery protocols or specialized techniques. One example of this is the quick adoption of adequate lymph node retrieval in colectomy by the CR field. A retrospective review of patients undergoing colectomy for colon cancer from 1994–2009 at a single institution (371 patients) demonstrated that lymph node retrieval during colectomy significantly increased when surgeons had CR fellowship training (19.9 lymph nodes retrieved versus 14.8, $p < .01$).¹⁸ While this difference would not benefit in-hospital mortality (the outcome in our analysis), it does have bearing on patients' future health. Finally, sub-specialty training allows general surgery residency graduates the opportunity to glean more practical know-how with supervised autonomy during their fellowship. Sadly, this need for a

surgical finishing school is thought (by some) to be sorely needed for today's general surgery graduates. A survey of the membership of the fellowship council in 2012 demonstrated that fellowship program directors believed that 66% of incoming fellows were unable to operate for 30 unsupervised minutes of a major procedure.¹⁹ The corollary that these deficiencies were made up over the course of fellowship was assumed. In short, it is clear that the benefit of sub-specialty training has multiple contributors: increased surgical volume in specific procedures, increased sub-specialization in a field, and likelihood to practice in a hospital that has high volume in that particular procedure.

This study had some significant limitations. It is a population study without the granularity of institutional chart review and the lack of bias of a randomized trial. The data is obtained by ICD-9 code which is dependent on accurate coding at a variety of institutions. ICD-9 coding is notoriously difficult to parse into urgent and elective cases. The authors hope that our sensitivity analysis performed only in patients with CR malignancy helps disabuse some of these concerns. Another limitation is that this study investigated board-certified CR surgeons versus all other surgeons. Using available data, we were unable to identify board-eligible CR surgeons who had completed their fellowship but had yet to complete their CR surgery boards successfully. These surgeons were included with the general surgeons. However, it is likely that the bias introduced by this misclassification would err towards the null (no difference between CR surgeons and general surgeons) and therefore can be ignored. While there are limitations of this study, there are also benefits. This is a population study examining the health records of the population of New York State, a large state with a diverse patient population and multiple types of healthcare institutions. This study also includes patients of all ages, making it applicable to the general United States population. Many population studies looking at hospital and surgeon volume are performed in the Medicare population, including only patients over the age of 65.

Finally, this study brings up areas deserving of further investigation, in particular, the incidence of stoma creation in operations performed by CR surgeons versus general surgeons. Our study demonstrated that the incidence of all stoma (ileostomy and colostomy) was the same in patients who underwent surgery by CR surgeons and by general surgeons. While there was no difference in all stomas, there was a decreased likelihood of colostomy for patients who underwent surgery with CR surgeons. This difference was stronger when the operation was performed for diverticular disease (but was also present in those who underwent surgery for malignancy). A decreased incidence of colostomy creation in patients with diverticulitis who undergo surgery with high volume surgeons has been reported in previous literature.²⁰ While perforation was adjusted for in our multivariate analysis assessing colostomy creation, this outcome may be due to inadequate control for urgent operations (for example, those patients who present with Hinchey IV diverticulitis). This difference could also indicate a progression towards diverting ileostomy and primary anastomosis in the treatment of perforated diverticulitis by CR surgeons. Further, more granular, investigation into the decision-making and outcomes following these operations is indicated.

CONCLUSION:

In conclusion, this study demonstrates that even after accounting for annual surgeon and hospital volume, patients have lower inpatient mortality, decreased incidence of colostomy, and shorter length of stay when undergoing a colectomy or proctectomy performed by a CR surgeon compared to a general surgeon. As the field of CR surgery continues to grow, more patients may benefit from these surgeons' sub-specialty training.

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Figure 1.
Change in percentage of colectomy/proctectomy performed by CR surgeons over time

Table 1:

(ICD-9 codes used to create study population)

Procedure Type	ICD-9 codes
Partial colectomy	45.70 45.71 45.79
Right colectomy	45.72 45.73
Transverse colectomy	45.74
Sigmoid Colectomy	45.75
Left colectomy	45.76
Total colectomy	45.80 45.82 45.83
Laparoscopic total colectomy	45.81
Laparoscopic colectomy	173.1 173.9
Laparoscopic right colectomy	173.2 173.3
Laparoscopic transverse colectomy	173.4
Laparoscopic left colectomy	173.5
Laparoscopic sigmoid colectomy	173.6
Laparoscopic proctectomy	484.2
Abdominoperineal Resection (APR)	485.0 485.2 485.9
Laparoscopic APR	485.1
Transanal Rectosigmoidectomy	486.1
Anterior Resection	486.2 486.3
Posterior Resection	486.4

Table 2:

Demographics (stratified by CR surgery training status):

Demographic	No CR training	CR training	P-value
Age	64.5 years	62.3 years	<.01
Female Sex	55.0%	53.3%	<.01
Non-white Race	25.2%	19.9%	<.01
High Charlson (≥ 3)	37.0%	32.7%	<.01
Proctectomy	11.3%	29.4%	<.01
Academic Medical Center	28.9%	47.3%	<.01
Cancer	38.4%	46.5%	<.01
IBD	3.8%	8.3%	<.01
Diverticulitis	4.5%	5.7%	<.01
Perforation	5.7%	1.8%	<.01
Ischemia	5.3%	1.7%	<.01
Hemorrhage	4.2%	2.9%	<.01
Rectal Prolapse	0.6%	4.1%	<.01
Laparoscopic	13.4%	27.9%	<.01
Robotic	0.4%	3.8%	<.01
Complications	16.0%	11.3%	<.01
Died	6.1%	1.6%	<.01

Table 3:

Model demonstrating benefit of CR surgery training on inpatient mortality (adjusted for age):

Demographic	OR	P value
CR surgery training	0.76	<.01
Charlson Comorbidity Index >3	2.39	<.01
Female	0.78	<.01
Caucasian Race	0.92	0.03
Colectomy	1.88	<.01
Ischemia	5.52	<.01
Cancer	0.36	<.01
Perforation	3.62	<.01
Diverticulitis	0.97	0.56
IBD	1.48	<.01
Laparoscopic procedure	0.34	<.01
Surgeon Volume	0.99	<.01
Hospital Volume	0.99	<.01

Table 4:

Sensitivity Analysis restricted only to patients with malignancy. Model demonstrating benefit of CR surgery training on inpatient mortality (adjusted for age)

Demographic	OR	P value
CR surgery training	0.79	<.01
Charlson Comorbidity Index >3	2.77	<.01
Female	0.74	<.01
Caucasian Race	1.04	0.44
Colectomy	1.57	<.01
Laparoscopic procedure	0.35	<.01
Surgeon Volume	0.99	<.01
Hospital Volume	0.99	<.01

Table 5:

Change in percentage of colectomy/proctectomy performed by CR surgeons over time

Year	No CR Training	CR Training
2000	83.4%	16.6%
2001	82.4%	17.6%
2002	81.2%	18.8%
2003	80.0%	20.0%
2004	78.9%	21.1%
2005	77.5%	22.5%
2006	76.2%	23.8%
2007	74.3%	25.7%
2008	71.6%	28.4%
2009	70.5%	29.5%
2010	67.8%	32.2%
2011	65.5%	34.5%
2012	63.7%	36.3%
2013	62.7%	37.3%
2014	59.9%	40.1%
Average	73.3%	26.7%

P <.01