Published in final edited form as:
J Am Coll Surg. 2012 June ; 214(6): 909–918.e1. doi:10.1016/j.jamcollsurg.2012.03.010.

Adoption of Laparoscopy for Elective Colorectal Resection: A Report from Surgical Care and Outcomes Assessment Program

The Surgical Care and Outcomes Assessment Program (SCOAP) Collaborative, **Steve Kwon, MD, MPH**[1], **Richard Billingham, MD, FACS**[2], **Ellen Farrokhi, MD, FACS**[3], **Michael Florence, MD, FACS**[2], **Daniel Herzig, MD, FACS**[4], **Karen Horvath, MD, FACS**[1], **Terry Rogers, MD**[3], **Scott Steele, MD, FACS**[5], **Rebecca Symons, MPH**[1], **Richard Thirlby, MD, FACS**[6], **Mark Whiteford, MD, FACS**[7], and **David Flum, MD, MPH, FACS**[1]

[1]Department of Surgery, University of Washington, Seattle, WA

[2]Department of Surgery, Swedish Medical Center, Seattle, WA

[3]Foundation for Healthcare Quality, Seattle, WA

[4]Department of Surgery, Oregon Health and Sciences University, Portland, OR

[5]Department of Surgery, Madigan Army Medical Center, Fort Lewis, WA

[6]Department of Surgery, Virginia Mason Medical Center, Seattle, WA

[7]Department of Surgery, The Oregon Clinic, Portland, OR

Abstract

Background—The purpose of this study was to evaluate the adoption of laparoscopic colon surgery and assess its impact in the community at large.

Study Design—The Surgical Care and Outcomes Assessment Program (SCOAP) is a quality improvement (QI) benchmarking initiative in the Northwest using medical record-based data. We evaluated the use of laparoscopy and a composite of adverse events (CAE; death or clinical reintervention) for patients undergoing elective colorectal surgery at 48 hospitals from 4th quarter of 2005 through 4th quarter of 2010.

Results—Of the 9,705 patients undergoing elective colorectal surgeries (mean age 60.6 ± 15.6 (SD) yrs; 55.2% women), 38.0% were performed laparoscopically (17.8% laparoscopic procedures converted to open). The use of laparoscopic procedures increased from 23.3% in 2005 quarter 4 to 41.6% in 2010 quarter 4 (trend over study period, $p<0.001$). After adjustment (age, sex, albumin levels, diabetes, body mass index, comorbidity index, cancer diagnosis, year, hospital bed size and urban vs. rural location), the risk of transfusions [odds ratio (OR) 0.52, 95% CI 0.39–0.7], wound infections (OR 0.45, 95% CI 0.34–0.61), and CAEs (OR 0.58; 95%CI 0.43–0.79) were all significantly lower with laparoscopy. Within those hospitals that had been in SCOAP since 2006, hospitals where laparoscopy was most commonly used also had a significant increase

Correspondence address: David R. Flum, MD, MPH, Professor, University of Washington, Department of Surgery, 1959 N.E. Pacific St. Rm AA 404, Box 356410, Seattle, WA 98195-6410, Phone: (206) 616-5440, Fax: (206) 543-8136, daveflum@u.washington.edu.

Disclosure Information: Nothing to disclose.

Presented at the American College of Surgeons 97th Annual Clinical Congress, San Francisco, CA, October 2011.

in the volume of all types of colon surgery (202 cases per hospital in 2010 from 112 cases per hospital in 2006, 80.4% increase), and in particular the number of resections for non-cancer diagnoses and right sided pathology.

Conclusions—The use of laparoscopic colorectal resection increased in the Northwest. Increased adoption of laparoscopic colectomies was associated with greater use of all types of colorectal surgery.

Keywords

adoption of laparoscopy; utilization of laparoscopy; colorectal surgery

INTRODUCTION

The introduction and rapid adoption of a laparoscopic approach to cholecystectomy revolutionized the surgical treatment of gallbladder disease. Within a few years of the first laparoscopic cholecystectomy in 1985, this technique grew to 73.7% of all cholecystectomies being performed laparoscopically by 1992.[1] Laparoscopic cholecystectomy significant reduced the length of hospitalization and costs.[2, 3] Studies have also demonstrated that the introduction of laparoscopy has led to increased rates of cholecystectomies being performed in a given region/hospital. [4–7] These studies have suggested that laparoscopy has led to lowered threshold for intervention such that surgery is performed for less severe gall bladder disease.

Conversely, despite extensive evidence demonstrating the benefits of laparoscopic colorectal operations in 2000s[8–16], adoption of laparoscopic colorectal operations appears to have been slower paced.[17–19] The technique was first reported in 1991 with one estimate of growth from 3.6% of colorectal operations being performed laparoscopically in 1994 to 24.3% in 2005.[20] These lower adoption rates may be in part due to studies likely underestimating the number of these operations with the use of administrative datasets. Before October 2008, the ICD-9-CM procedure code was not specific for laparoscopic colectomies (there are still no ICD9 procedure codes for laparoscopic low anterior resections). A common strategy employed to identify these cases involved the use of an inconsistently applied modifier code for laparoscopy (ICD-9-CM 54.21) or “conversion to open” codes.

Furthermore, most of the reports about the efficacy of laparoscopic colon surgery come from academic or single center experiences[8, 9, 11, 16, 21–25] and have been rather narrowly focused on technique and comparative outcomes rather than on the impact of laparoscopic approaches on the threshold for colorectal operations. The purpose of this study was to assess whether in the community at large the number of colon surgeries changed with the adoption of the laparoscopic technique and to track the actual rate of adoption and outcomes of laparoscopy.

To address these issues we evaluated clinical data drawn from hospitals participating in Washington State’s Surgical Care and Outcomes Assessment Program (SCOAP), a prospectively-gathered clinical surveillance and benchmarking based quality improvement (QI) collaboarative (http://www.scoap.org), now implemented at nearly all Washington statewide hospitals where surgery is performed (n= 60) and some Orgeon hospitals.[26] Our hypothesis was that the use of elective surgery for diverticulitis, for any indication of right colon resection and the overall use of colon surgery would increase at a higher rate in the hospitals that had a greater adoption of the laparoscopic technique compared to hospitals that were slower to adopt laparoscopic surgery.

METHODS

Study Design

This study was approved by the University of Washington Human Subject Review Committee and the Washington State Department of Health. We conducted a retrospective cohort study using an in-hospital clinical registry (SCOAP). There are 60 hospitals currently participating in SCOAP however only data from 48 hospitals that perform elective colorectal operations was available by the time of this analysis (see Table, Supplemental Digital Content 1, which lists the names of the hospitals in SCOAP). We included records of inpatient hospitalization between 4th quarter of 2005 through 4th quarter of 2010 at the 48 hospitals across the Northwest region that performed elective colon/rectal procedures.

Data Sources and Characteristics

SCOAP records were used to obtain sociodemographic and clinical characteristics. Operative details including the use of laparoscopy, clinical indications for surgery, operative time, laboratory values, and post-operative adverse events were taken from documented hospital records using a set of standard definitions. Monthly quality control teleconferences with abstractors were used to ensure that charts were being recorded and evaluated in a similar fashion. Moreover, each hospital had a group of involved surgeons and QI teams who audited the process of data collection. A yearly auditing of all sites asssured >98% data validity for all involved metrics.

Variable Definitions

Patient risk factors—We used the Deyo modification of the Charlson comorbidity index to calculate a weighted index of comorbid conditions for each patient with the information gathered from clinical charts.[27] Scores range from 0 to 3+, where 0 indicates the absence of comorbid conditions and the score was truncated at 3 and above.

Hospital characteristics—SCOAP records were used to obtain hospital information. We had information on number of beds, rural vs. urban, and teaching vs. non-teaching status for each hospital.

Laparoscopy—Method of operation was identified from the operative report and operating room logs looking for specific identification of open, laparoscopic, laparoscopic converted to open, and laparoscopic/hand-assisted surgical approaches. The latter three categories were considered laparoscopic procedures based on an intention to treat basis.

Type of operation—Operations included were right/transverse hemicolectomy, left hemicolectomy, low anterior resection, total abdominal colectomy, stoma takedown, and abdominal perineal resection (APR).

Outcomes—The perioperative outcomes of interest was rates of in-hospital mortality, transfusions, wound infections, clinically relevant leaks, and harvesting of 12+ lymph nodes (LN) in cancer patients. We also looked at operative time and length of stay (LOS). A composite of adverse events (CAE) was created as a composite of operative interventions and deaths. Composite of operative interventions were defined as an in hospital adverse event that resulted in an unplanned postoperative procedure including a return to the operating room for a formation of a new ostomy, revision of the anastomosis, re-exploration/washout, evisceration, operation for postoperative bleeding, or irrigation and drainage of an intra-abdominal abscess, or a non-operative percutaneous drain placement, and/or operative drain placement.

Statistical Analysis

Patient and hospital characteristics were summarized using frequency distributions for categorical variables, and means and standard deviations for continuous variables stratified by laparoscopic vs. open approaches. Patients with missing information for a variable were dropped when performing those analyses involving that variable. With the same stratification, rates of transfusion, harvesting of 12+ LNs, wound infections, clinically relevant leaks, in-hospital mortality, and CAEs were summarized using frequency distributions. Pearson chi-square statistics were used to compare characteristics and unadjusted event rates. To assess the differences in trend across the years, we obtained the total number of colorectal operations across calendar years by hospitals categorized into tertiles of laparoscopy use. After obtaining the Pearson's correlation coefficient of the number of colorectal operations over time for each of the tertile groups, we compared the correlation coefficient with each other using a nonparametric trend test. Operative time and LOS between laparoscopic and open approaches were compared using the Student's t-test. Logistic regression models were created to evaluate the association between laparoscopic approaches and outcomes adjusting for patient, clinical, and operative characteristics identified as statistically significant ($p<0.05$) on univariate evaluation or identified as clinically important in previous studies. In all our logistic regression models looking at outcomes, we controlled for hospital effects using multi-level models with hospital-level random effects.

To assess those factors associated with use of laparoscopy, we created logistic regression models using indication for surgery (i.e. diverticular vs. cancer) and type of operation (i.e. right hemicolectomy vs. low anterior resection) as predictor variables adjusting for relevant patient, clinical, and operative characteristics. We evaluated the impact that laparoscopy had on the "threshold" surgeons appeared to have in offering elective colorectal operations to patients evaluating hospitals that had been in SCOAP since 2006 (to evaluate full time trends). We categorized hospitals into tertiles according to use of laparoscopy in colorectal surgery. The average number of elective colorectal operations performed per hospital was calculated for each calendar year based on level of use (highest, mid, lowest tertile) of laparoscopy. Linear regression model using interaction variables was created to compare the differences in the trend of case volume of these groups of hospitals (i.e., highest vs. lowest tertile) over the study period. This was repeated for procedures performed for diverticulitis and right hemicolectomies (overall and without a cancer diagnosis). STATA was used for all analyses (Version 11, STATACorp, College Station, TX).

RESULTS

9,705 patients underwent elective colorectal procedures during the 5-year inclusion time frame, with 3,685 patients (38.0%; mean age 59.1±15.3 yrs; 52.2% women) undergoing a laparoscopic approach. Over the course of the study period, laparoscopy use increased (23.3% in 2005 to 41.6% in 2010, p for trend<0.001) (Table 1). The overall conversion rate was 17.8% (23.5% in 2005 and 18.1% in 2010, p for trend=0.5) (Table 1). In colorectal operations for cancer, there was a slower rate of increase in laparoscopy use (Table 1). Patients whose procedures were performed laparoscopically were younger, more likely to be males, and have less comorbidities, Medicaid insurance, and albumin level lower than 3 g/dL (Table 2). In considering operative characteristics, laparoscopic approach was used more for right colectomies and diverticular disease, but less for stoma takedowns, APR, and cancer operations (Table 2). Those procedures performed laparoscopically were more likely to be at a hospital with size ≥ 200 beds ($p=0.02$) and urban location ($p<0.001$). Teaching status of the hospital was not associated with more frequent usage of laparoscopy procedures (Table 2).

The unadjusted rates of in-patient mortality (0.6% vs. 1.6%, p<0.001), wound infections (5.6% vs. 10.8%, p<0.001), clinically relevant leaks (4.1% vs. 5.4%, p=0.004), transfusions (4.3% vs. 9.9%, p<0.001), and CAEs (4.5% vs. 6.5%, p<0.001) were lower among those who had a laparoscopic operation. Operative time was longer by about 7 minutes (159.2 ± 86.9 vs. 152.7 ± 98.9, p=0.001) and LOS lower with laparoscopy (6.2 vs. 8.6 days, p<0.001). There were no differences in the rate of harvesting 12+ lymph nodes in cancer procedures (87.8% for open vs. 87.6% for laparoscopy, p=0.9).

After adjustment for relevant patient and clinical characteristics, the odds of CAEs were 42% lower with laparoscopic approach compared to the open approach (OR 0.58, 95% CI 0.43–0.79) (Table 3). The odds of transfusions (OR 0.52, 95% CI 0.39–0.7) and wound infections (OR 0.45, 95% CI 0.34–0.61) were all lower for patients undergoing laparoscopic procedure compared to the open approach (Table 3). Similar trends were noted when these outcomes were stratified by different type of operations.

After adjustment for calendar year, hospital factors (bed size and urban vs. rural location) and other patient characteristics (age, sex, albumin levels, diabetes, body mass index, Charlson's comorbidity index, and cancer), the odds of laparoscopic use were nearly 2 times higher for a diagnosis of diverticulitis compared to colorectal operations for any other indication (OR 2.02, 95% CI 1.7–2.41). After adjustment, the odds of laparoscopy use for right hemicolectomies were 35% higher compared to any other types of colorectal operation (OR 1.35, 95% CI 1.19–1.54) (Table 4).

The average colorectal case volume per year of all colorectal operations at any given hospital was associated with the extent of adoption of laparoscopy (Figure 1A). Hospitals where surgeons used laparoscopy most frequently (highest tertile) had the greatest increase in yearly case volume compared to hospitals where surgeons had the lowest rates of laparoscopic adoption (lowest tertile) (p<0.001). There was no significant increase in the trend of total cases performed in the middle tertile hospitals compared to the lowest tertile hospitals (p=0.13). The increase in the numbers of operations for right colon and diverticulitis from 2006 to 2010 were higher at the highest tertile hospitals (80.1% increase for right hemicolectomies and 140% increase for diverticulitis) compared to the lowest tertile hospitals (43.6% increase for right hemicolectomies and 31.3% increase for diverticulitis) (p<0.001 for both). There were no significant differences for these two operations between the middle tertile hospitals (27.6% increase for right hemicolectomies and 64.5% increase for diverticulitis) and the lowest tertile hospitals (p=0.11 for right hemicolectomies and p=0.23 for diverticulitis) (Figure 1B).

DISCUSSION

In this regional evaluation of patients treated in a wide range of hospitals and by a diverse group of surgeons throughout Washington State and in Portland, Oregon, we found that the use of laparoscopy in colorectal operations increased up to 41.6% by 2010. While still lower in comparison to adoption rates in cholecystectomy and anitreflux surgeries[1, 28], these rates reflect a closer estimate of laparoscopic use because we did not rely on notoriously inaccurate billing codes. We found that the laparoscopy adoption rates are higher than national estimates using those less granular data sources. We found that better preoperative nutritional status, hospital characteristics (urban location and bed size), diverticular diseases, and right hemicolectomies were factors associated with more laparoscopy use. We observed the greatest increase in the total number of colorectal operations in the hospitals with the highest laparoscopy adoption rates. We also found a significant increase in the number of right colon surgeries and elective surgeries for diverticulitis in these hospitals.

Reports of laparoscopy use in colorectal operations have varied widely depending on the data source. Studies using administrative databases (National Inpatient Sample) have reported rates around 10% in the 2000s (below 10% for cancer cases).[17–19] Interestingly, two studies using the same database in the same time period (2005 to 2007) reported two different estimates of the percentages of use of laparoscopy in benign diseases (11.8%[17] vs. 27.2%[18]) highlighting the potential for inaccuracies and variations in coding that undermine the credibility of that data source. In comparison, studies using the NSQIP database[29] and database from American Board of Colon and Rectal Surgery (ABCRS)[20] have reported much higher adoption rates of 31.1% in 2006 to 2007 and 24.3% in 2005, respectively. Given that hospitals that provide data for NSQIP and ABCRS tend to be large, academic medical centers, it remains to be determined if these percentages are reflective of the experience in the general community. This is the first study looking at the utilization rate of laparoscopy in colorectal operations in a community setting across diverse institutions using direct data drawn from operative reports. The conversion rates to open procedure have been reported to be as high as 19% [meta-analysis of 3 randomized controlled trials (RCTs) of 1990s to early 2000s][21] to 36% using an administrative database from 2005 to 2007.[17] Other RCTs have reported much lower conversion rates around 5%.[10] We observed an overall conversion rate of 17.8% from 2006 to 2010 without a significant change over the course of the study. Other studies suggest that more experience in laparoscopy is associated with a reduction in operative time, lower conversion rates, and lower intra-operative and postoperative complications.[30–32]

There has been extensive evidence in the early 2000s suggesting that laparoscopic colectomy (LC) provides improved short-term and equivalent long-term outcomes as open colectomies (OC) for both benign and malignant disease. LC has been demonstrated to be associated with shorter hospital stays[8, 13], faster return of bowel function[13, 33], decreased number of days on narcotics[8, 33], improved pulmonary function postoperatively[33], shorter time off work[34], increased rates of routine hospital discharge[12, 15, 35], and lower rates of incisional hernias and small bowel obstructions.[36, 37, 38] The laparoscopic approach was associated with an improved 30-day mortality rate in a single-institution randomized study, while similar rates of 30-day mortality, intraoperative complications, and reoperations have been noted in multi-institutional trials.[8,13] Evidence of whether such benefits extend into community settings has been limited. SCOAP provided an opportunity to assess the impact of LC in the community including all level of surgeon skill and training, and all hospital types and size. In this setting, we found that the adjusted odds of CAEs were 42% lower with the laparoscopic approach. Similarly, the odds of transfusions were 48% lower and wound infections were 55% lower for patients undergoing laparoscopic procedure, while outcomes for malignant cases including the harvesting rates of 12+ lymph nodes were similar for open and laparoscopic approaches. Despite these benefits, adoption in the community at large is still limited, with the vast majority of these cases still being performed in specialized centers. Reasons for this generalized lack of conversion range from lack of experience and technical skills to complex disease processes associated with colorectal surgery (i.e. Crohn’s disease, colovesicular fistula), long operative times, and concerns for oncological outcomes. While there is level 1 evidence suggesting better short term and at least as equivalent oncologic outcomes as open procedures[8, 11, 13, 16, 23, 25, 39], we found no increase in the use of laparoscopy for cancer operations.

The slow adoption rate has also been attributed to technical challenges of laparoscopy in colorectal operations requiring a steep learning curve with significant number of cases.[18, 30, 32, 40] As expected, there was a positive relationship between laparoscopy use and right hemicolectomy while a negative association was seen with a more technically challenging low anterior resections to support this theory. Urban location of the hospital, hospital size less than 200 beds, and higher albumin levels were also associated with increased likelihood of using laparoscopy when adjusted for other variables. It is unclear why hospital size less than 200 beds was associated with increased use. It may be that there are more dedicated colorectal or surgeons with minimally invasive training in these centers. Larger hospital size may not be as important in increased laparoscopy use as having surgeons who are trained in laparoscopic colorectal operations.

Introduction of laparoscopy in cholecystectomies led to an increased number of operations per capita in the 1990s.[5] Similarly, we found that the number of all colorectal procedures (open and laparoscopic) increased most significantly in the hospitals with the greatest adoption of laparoscopy compared to those hospitals with low laparoscopy adoption rates. A similar pattern was again observed when looking just at colectomies that were performed for right sided disease or for a diagnosis of diverticulitis. This may indicate that increased laparoscopy use, particularly for technically more straight forward procedures and for non-oncologic indications, has led to lowered threshold for surgeons to perform these types of operations. If surgeons were simply attempting to use laparoscopy more for right colon surgery and/or elective surgery for diverticular disease then we would only observe a shift in the proportion of open to laparoscopic surgeries. This would not have an impact on the total number of the surgeries. Another explanation for this finding may relate to an increasing incidence of diverticular disease or right hemicolectomies over time at newly joining SCOAP hospitals. To address some of these concerns, we restricted our analysis to hospitals that were in SCOAP since 2006. It may also be possible that hospitals that were increasingly performing laparoscopic surgery began capturing a greater proportion of the elective colon surgery marketplace.

There are some limitations to our study. There may have been unobserved factors associated with changes in laparoscopy use and case volume. As we focused on elective operations, patients may have self-selected to undergo operations at high laparoscopy centers. Although SCOAP comprises a rich clinical dataset, it lacks information on surgeon factors such as experience and training. Increased number of patients may have been referred to new colorectal surgeons with more training in laparoscopic surgery. In the SCOAP network most hospitals have 1–2 surgeons doing most of the colorectal resections, and separate doctor-level analysis was not performed secondary to low number of procedures by clinicians and a lack of an accurate surgeon identification variable. We adjusted for hospital sites in our hierarchical modeling. This study provides the most recent experience of laparoscopy with data from 2010. The disadvantage is that SCOAP started in 2006 and we do not have a comparison data on laparoscopy use and outcomes prior to the publication of the pivotal trials that sanctioned the use of laparoscopy. Our study represents the experience in Washington State and may not be representative of other states. However, the strength of SCOAP data is that its results are drawn from hospitals and communities of all types across nearly the entire State of Washington and some in Oregon. Lastly, to further address the issue of shifting threshold for operations, in 2010 SCOAP began collecting data about the severity of diverticulitis, number of prior episodes, hospitalizations, and other parameters that might be helpful in assessing the issue of changing thresholds. Since only one year of data is available we were unable to include those data points in this analysis.

In conclusion, the utilization rate of laparoscopy in colorectal surgery increased to 41% in 2010. Laparoscopic resection was associated with lower risk adjusted rates of wound infections, transfusions, and composite adverse events compared to open resections. Indication for operation (diverticular diseases vs. malignant conditions), and technical ease of procedure (right hemicolectomies vs. low anterior resections) were associated with the increased adoption of laparoscopy. The total case volume, particularly for right hemicolectomies and colectomies for diverticular disease, was related to the degree of adoption of laparoscopy at hospitals suggesting that with the adoption of laparoscopy has come a change in the threshold for surgical interventions similar to that seen after the introduction of laparoscopic cholecystectomy. Assessing whether or not a change in threshold for operation has occurred requires more robust data about operative decision making including patient and physician perspectives.

Acknowledgments

SCOAP is a program of the Foundation for Healthcare Quality. SCOAP is supported by a grant from Washington State's Life Science Discovery Fund and Agency for Healthcare Research and Quality Grant Number 1 R01 HS 20025-01.

References

1. Kemp JA, Zuckerman RS, Finlayson SR. Trends in adoption of laparoscopic cholecystectomy in rural versus urban hospitals. J Am Coll Surg. 2008; 206:28–32. [PubMed: 18155565]
2. Bosch F, Wehrman U, Saeger HD, Kirch W. Laparoscopic or open conventional cholecystectomy: clinical and economic considerations. Eur J Surg. 2002; 168:270–7. [PubMed: 12375608]
3. Kelley JE, Burrus RG, Burns RP, et al. Safety, efficacy, cost, and morbidity of laparoscopic versus open cholecystectomy: a prospective analysis of 228 consecutive patients. Am Surg. 1993; 59:23–7. [PubMed: 8480927]
4. Cohen MM, Young W, Theriault ME, Hernandez R. Has laparoscopic cholecystectomy changed patterns of practice and patient outcome in Ontario? CMAJ. 1996; 154:491–500. [PubMed: 8630838]
5. Legorreta AP, Silber JH, Costantino GN, et al. Increased cholecystectomy rate after the introduction of laparoscopic cholecystectomy. JAMA. 1993; 270:1429–32. [PubMed: 8371441]
6. Pedersen G, Hoem D, Andren-Sandberg A. Influence of laparoscopic cholecystectomy on the prevalence of operations for gallstones in Norway. Eur J Surg. 2002; 168:464–9. [PubMed: 12549686]
7. Persson GE, Ros AG, Thulin AJ. Surgical treatment of gallstones: changes in a defined population during a 20-year period. Eur J Surg. 2002; 168:13–7. [PubMed: 12022365]
8. A comparison of laparoscopically assisted and open colectomy for colon cancer. N Engl J Med. 2004; 350:2050–9. [PubMed: 15141043]
9. Bilimoria KY, Bentrem DJ, Merkow RP, et al. Laparoscopic-assisted vs. open colectomy for cancer: comparison of short-term outcomes from 121 hospitals. J Gastrointest Surg. 2008; 12:2001–9. [PubMed: 18575941]
10. Braga M, Frasson M, Vignali A, et al. Laparoscopic vs. open colectomy in cancer patients: long-term complications, quality of life, and survival. Dis Colon Rectum. 2005; 48:2217–23. [PubMed: 16228828]
11. 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; 365:1718–26. [PubMed: 15894098]
12. Guller U, Jain N, Hervey S, et al. Laparoscopic vs open colectomy: outcomes comparison based on large nationwide databases. Arch Surg. 2003; 138:1179–86. [PubMed: 14609864]
13. 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; 359:2224–9. [PubMed: 12103285]
14. Schwenk W, Haase O, Neudecker J, Muller JM. Short term benefits for laparoscopic colorectal resection. Cochrane Database Syst Rev. 2005:CD003145. [PubMed: 16034888]
15. Stocchi L, Nelson H, Young-Fadok TM, et al. Safety and advantages of laparoscopic vs. open colectomy in the elderly: matched-control study. Dis Colon Rectum. 2000; 43:326–32. [PubMed: 10733113]
16. Weeks JC, Nelson H, Gelber S, et al. Short-term quality-of-life outcomes following laparoscopic-assisted colectomy vs open colectomy for colon cancer: a randomized trial. JAMA. 2002; 287:321–8. [PubMed: 11790211]

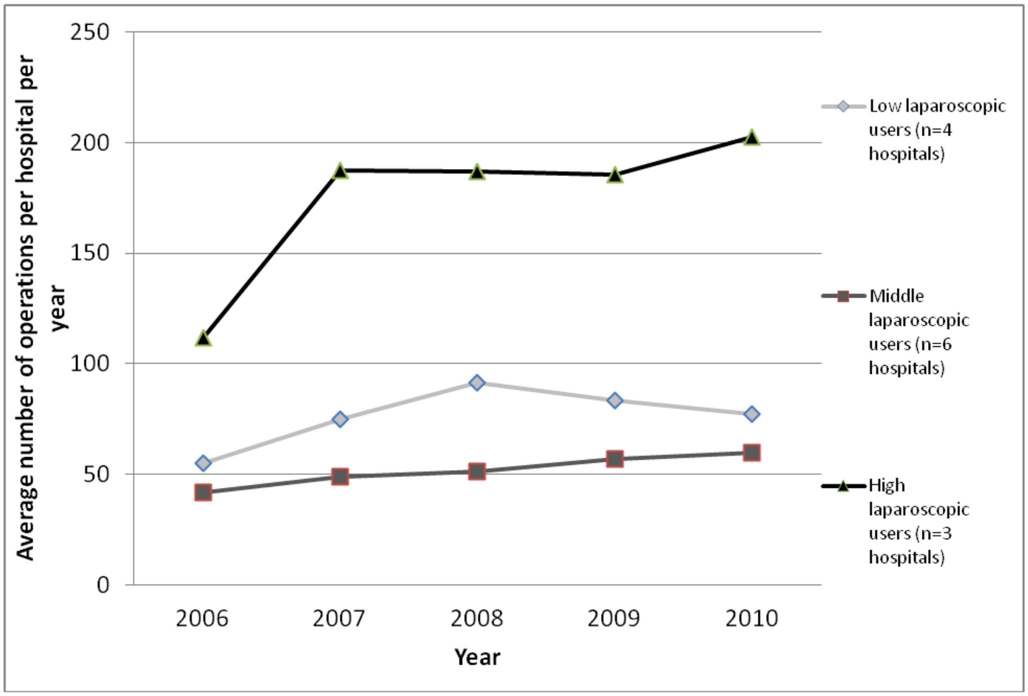
17. Rea JD, Cone MM, Diggs BS, et al. Utilization of Laparoscopic Colectomy in the United States Before and After the Clinical Outcomes of Surgical Therapy Study Group Trial. Ann Surg. 2011; 254:281–8. [PubMed: 21685791]
18. Robinson CN, Chen GJ, Balentine CJ, et al. Minimally invasive surgery is underutilized for colon cancer. Ann Surg Oncol. 2011; 18:1412–8. [PubMed: 21213059]
19. Kemp JA, Finlayson SR. Nationwide trends in laparoscopic colectomy from 2000 to 2004. Surg Endosc. 2008; 22:1181–7. [PubMed: 18246394]
20. Schoetz DJ Jr. Evolving practice patterns in colon and rectal surgery. J Am Coll Surg. 2006; 203:322–7. [PubMed: 16931304]
21. 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. [PubMed: 17372057]
22. Braga M, Vignali A, Zuliani W, et al. Laparoscopic versus open colorectal surgery: cost-benefit analysis in a single-center randomized trial. Ann Surg. 2005; 242:890–5. discussion 895–6. [PubMed: 16327499]
23. Fleshman J, Sargent DJ, Green E, et al. Laparoscopic colectomy for cancer is not inferior to open surgery based on 5-year data from the COST Study Group trial. Ann Surg. 2007; 246:655–62. discussion 662–4. [PubMed: 17893502]
24. Kennedy GD, Heise C, Rajamanickam V, et al. Laparoscopy decreases postoperative complication rates after abdominal colectomy: results from the national surgical quality improvement program. Ann Surg. 2009; 249:596–601. [PubMed: 19300230]
25. 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. [PubMed: 18580199]
26. Flum DR, Fisher N, Thompson J, et al. Washington State's approach to variability in surgical processes/Outcomes: Surgical Clinical Outcomes Assessment Program (SCOAP). Surgery. 2005; 138:821–8. [PubMed: 16291381]
27. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. J Clin Epidemiol. 1992; 45:613–9. [PubMed: 1607900]
28. Finlayson SR, Laycock WS, Birkmeyer JD. National trends in utilization and outcomes of antireflux surgery. Surg Endosc. 2003; 17:864–7. [PubMed: 12632134]
29. Kiran RP, El-Gazzaz GH, Vogel JD, Remzi FH. Laparoscopic approach significantly reduces surgical site infections after colorectal surgery: data from national surgical quality improvement program. J Am Coll Surg. 2010; 211:232–8. [PubMed: 20670861]
30. Bennett CL, Stryker SJ, Ferreira MR, et al. The learning curve for laparoscopic colorectal surgery. Preliminary results from a prospective analysis of 1194 laparoscopic-assisted colectomies. Arch Surg. 1997; 132:41–4. discussion 45. [PubMed: 9006551]
31. Dincler S, Koller MT, Steurer J, et al. Multidimensional analysis of learning curves in laparoscopic sigmoid resection: eight-year results. Dis Colon Rectum. 2003; 46:1371–8. discussion 1378–9. [PubMed: 14530677]
32. Schlachta CM, Mamazza J, Seshadri PA, et al. Defining a learning curve for laparoscopic colorectal resections. Dis Colon Rectum. 2001; 44:217–22. [PubMed: 11227938]
33. Milsom JW, Bohm B, Hammerhofer KA, et al. A prospective, randomized trial comparing laparoscopic versus conventional techniques in colorectal cancer surgery: a preliminary report. J Am Coll Surg. 1998; 187:46–54. discussion 54–5. [PubMed: 9660024]
34. Chen HH, Wexner SD, Weiss EG, et al. Laparoscopic colectomy for benign colorectal disease is associated with a significant reduction in disability as compared with laparotomy. Surg Endosc. 1998; 12:1397–400. [PubMed: 9822465]
35. Stewart BT, Stitz RW, Lumley JW. Laparoscopically assisted colorectal surgery in the elderly. Br J Surg. 1999; 86:938–41. [PubMed: 10417569]
36. Eshuis EJ, Slors JF, Stokkers PC, et al. Long-term outcomes following laparoscopically assisted versus open ileocolic resection for Crohn's disease. Br J Surg. 2010; 97:563–8. [PubMed: 20175126]

37. Duepree HJ, Senagore AJ, Delaney CP, Fazio VW. Does means of access affect the incidence of small bowel obstruction and ventral hernia after bowel resection? Laparoscopy versus laparotomy. J Am Coll Surg. 2003; 197:177–81. [PubMed: 12892794]

38. Dowson HM, Bong JJ, Lovell DP, et al. Reduced adhesion formation following laparoscopic versus open colorectal surgery. Br J Surg. 2008; 95:909–14. [PubMed: 18509861]

39. 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; 25:3061–8. [PubMed: 17634484]

40. Tekkis PP, Senagore AJ, Delaney CP, Fazio VW. Evaluation of the learning curve in laparoscopic colorectal surgery: comparison of right-sided and left-sided resections. Ann Surg. 2005; 242:83–91. [PubMed: 15973105]



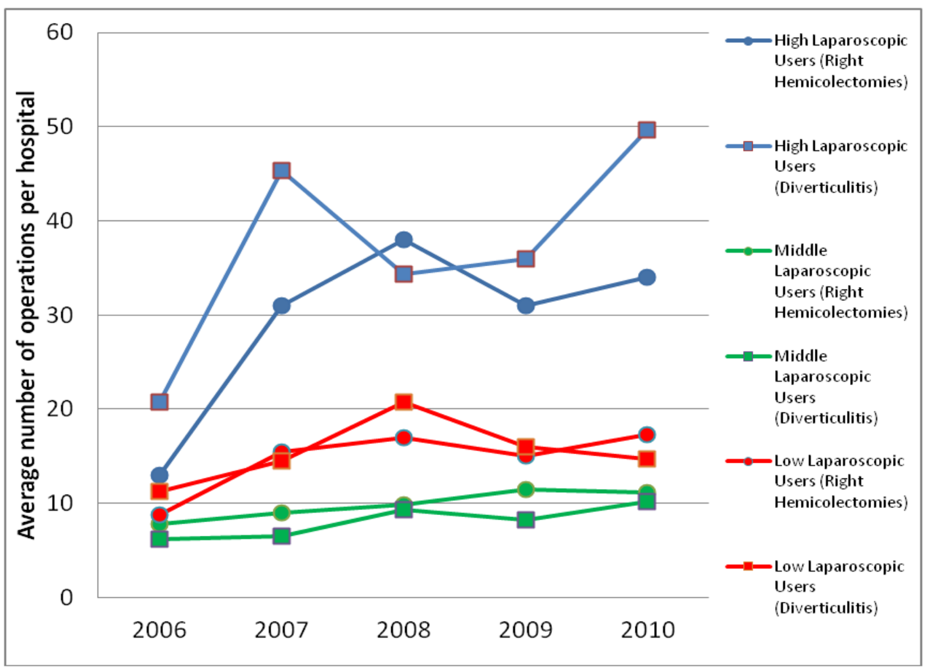


Figure 1.

Growth of colorectal operations in hospitals with different adoption rates of laparoscopy. Hospitals that had been in SCOAP since 2006 were categorized into tertiles of low (n=4), middle (n=6), high use (n=3) of laparoscopy using individual hospital’s aggregate data from 2006 to 2010. Using hospitals with data from 2006 to 2010, average numbers of elective colorectal operations per hospital per year are graphed for each calendar year for (A) Overall and (B) grouped by right hemicolectomies (non-cancer indications) and diverticular disease.

Table 1

Use of Laparoscopy in Elective Colorectal Operation from 2005 to 2010, for Overall (n=9,705) and for Cancer Indications (n=3,568).

	Total no. of cases (no. of hospitals)	Open, no. of cases (%)	Laparoscopic, no. of cases (%)*	Laparoscopic converted to open, no. of cases (%)†
Overall, n (%)				
2005‡	146 (8)	112 (76.7%)	34 (23.3%)	8 (23.5%)
2006	794 (13)	566 (71.3%)	228 (28.7%)	36 (15.8%)
2007	1,227 (17)	792 (64.5%)	435 (35.5%)	83 (19.1%)
2008	1,808 (27)	1,119 (61.9%)	689 (38.1%)	108 (15.7%)
2009	2,647 (40)	1,631 (61.6%)	1,016 (38.4%)	187 (18.4%)
2010	3,083 (48)	1,800 (58.4%)	1,283 (41.6%)	233 (18.2%)
Overall	9,705	6,020 (62.0%)	3,685 (38.0%)	655 (17.8%)
Cancer, n (%)				
2005‡	44 (4)	31 (70.5%)	13 (29.5%)	3 (23.1%)
2006	353 (12)	261 (73.9%)	92 (26.1%)	18 (19.6%)
2007	491 (17)	348 (70.9%)	143 (29.1%)	37 (25.9%)
2008	624 (26)	405 (64.9%)	219 (35.1%)	32 (14.6%)
2009	946 (39)	607 (64.2%)	339 (35.8%)	69 (20.4%)
2010	1,110 (45)	684 (61.6%)	426 (38.4%)	73 (17.1%)
Overall	3,568	2,336 (65.5%)	1,232 (34.5%)	232 (18.8%)

*p-value <0.001 for trend across calendar years for both overall and cancer indications.

†This cohort is also included in the laparoscopic column based on an intention to treat basis.

‡In 2005, we have only the 4th quarter data.

Table 2

Patient Sociodemographics and Hospital Characteristics Stratified by Open vs. Laparoscopic Procedures from 2005 to 2010

	Open	Laparoscopic	p Value
Patient demographics			
n	6,020	3,685	
Age, y, mean ± SD	61.6 ± 15.6	59.1 ± 15.3	<0.001
Female sex, n (%)	3,424 (56.9)	1,922 (52.2)	<0.001
Diabetes, n (%)	944 (15.7)	480 (13.0)	<0.001
Smoker, n (%)	1,087 (18.2)	617 (16.9)	0.1
Medicaid, n (%)	461 (7.8)	171 (4.7)	<0.001
Immunosuppression, n (%)	398 (6.6)	216 (5.9)	0.1
Albumin less than 3 g/dL, n (%)	590 (17.8)	165 (10.2)	<0.001
Body mass index, kg/m^2, mean ± SD	27.7 ± 7.4	27.9 ± 6.5	0.14
Charlson's Comorbididty index, n (%)			<0.001
0	4,187 (69.6)	2,696 (73.2)	
1	1,373 (22.8)	768 (20.8)	
2	370 (6.1)	170 (4.6)	
3+	90 (1.5)	51 (1.4)	
Mean± SD	0.4 ± 0.7	0.3 ± 0.6	
Indication for procedure, n (%)			
Malignancy	2,336 (38.8%)	1,232 (33.4%)	<0.001
Diverticular disease	1,043 (17.4%)	1,088 (29.8%)	<0.001
Type of operation, n (%)			
Right hemicolectomy	1,989 (30.0)	1,351 (36.7)	<0.001
Left hemicolectomy	1,137 (18.9)	612 (16.6)	0.005
Low anterior resection	2,201 (36.6)	1,412 (38.3)	0.08
Total colectomy	401 (6.7)	243 (6.6)	0.9
Stoma takedown	256 (4.3)	39 (1.1)	<0.001
Abdominal perineal resection	79 (1.3)	10 (0.3)	<0.001
Hospital characteristics			
n	5,909	3,600	
Hospital size ≥ 200 beds, n (%) *	4,983 (84.3%)	3,102 (86.2%)	0.02
Urban, n (%) *	5,549 (93.9%)	3,491 (97.0%)	<0.001

	Open	Laparoscopic	p Value
Residency, n (%) *	3,136 (53.1%)	1,954 (54.3%)	0.25

Missing number of data for each variable is as follows (the missing data were not included in the denominator when calculating the percentages): 3 for sex, 15 for diabetes, 69 for smoking, 93 for Medicaid insurance, 16 for immunosuppression, 388 for BMI, 4,805 for albumin, 53 for indication for procedure, 0 for type of operation, and 196 missing information for the 3 hospital characteristics listed.

* We had hospital characteristics information on 42 out of the 48 hospitals. There were 23 hospitals with ≥ 200 beds, 13 urban hospitals, 9 hospitals with residency programs/affiliation.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 3

Adjusted Logistic Regression Analysis to Evaluate the Association of Laparoscopy Use with Different Outcomes

	Transfusion (OR, 95% CI) (n=744/9,630)	12+ LNs in cancer patients (OR, 95% CI) (n=2,605/3,311)	Wound infections (OR, 95% CI) (n=858/9,705)	In-hospital deaths (OR, 95% CI) (n=116/9,690)	CAE[*] (OR, 95% CI) (n=557/9,705)
Laparoscopic surgery	0.52 (0.39–0.7)[†]	1.07 (0.87–1.31)	0.45 (0.34–0.61)[†]	0.62 (0.32–1.18)	0.58 (0.43–0.79)[†]
Age	1.02 (1.01–1.02)[†]	0.99 (0.99–1.01)	1.01 (1.01–1.02)[†]	1.06 (1.04–1.08)[†]	1.01 (1.0–1.02)[†]
Male sex[‡]	0.77 (0.63–0.96)[†]	0.82 (0.68–0.98)[†]	1.46 (1.2–1.78)[†]	1.62 (0.96–2.73)	1.77 (1.38–2.27)[†]
Albumin ≥ 3 g/dL (vs <3 g/dL)	0.42 (0.36–0.49)[†]	-	0.67 (0.58–0.77)[†]	0.3 (0.22–0.42)	0.65 (0.54–0.78)[†]
Diabetes	-	-	0.82 (0.58–1.15)	0.81 (0.41–1.61)	0.75 (0.51–1.12)
Immunosuppression	0.91 (0.63–1.33)	0.85 (0.51–1.44)	1.25 (0.89–1.75)	1.15 (0.44–3.01)	1.02 (0.63–1.64)
Smoker	-	-	1.24 (0.97–1.58)	1.44 (0.73–2.85)	1.29 (0.95–1.75)
Body mass index, kg/m^2	1.00 (0.99–1.01)	0.99 (0.97–0.99)	1.01 (0.99–1.02)	1.01 (0.97–1.05)	1.01 (0.99–1.03)
Charlson comorbidity index[‡]					
1	1.52 (1.2–1.94)[†]	0.99 (0.83–1.18)	0.97 (0.73–1.28)	2.48 (1.3–4.7)[†]	1.52 (1.09–2.11)[†]
2	2.36 (1.68–3.3)[†]	1.01 (0.74–1.36)	1.36 (0.89–2.07)	2.66 (1.06–6.67)[†]	1.46 (0.86–2.47)
3+	2.63 (1.42–4.87)[†]	0.45 (0.26–0.79)[†]	1.82 (0.96–3.47)	5.44 (1.66–17.78)[†]	3.58 (1.8–7.14)[†]
Year[‡]					
2006	2.0 (0.76–5.3)	5.03 (2.0–12.62)[†]	1.28 (0.48–3.38)	0.46 (0.04–5.8)	6.76 (0.86–52.97)
2007	1.01 (0.38–2.7)	11.89 (4.76–29.72)[†]	1.47 (0.57–3.81)	0.66 (0.06–6.8)	4.9 (0.63–38.31)
2008	1.24 (0.48–3.21)	22.39 (8.9–56.32)[†]	1.09 (0.42–2.77)	1.08 (0.12–9.69)	6.04 (0.79–46.26)
2009	1.29 (0.5–3.31)	25.84 (10.35–64.53)[†]	1.24 (0.49–3.11)	1.21 (0.14–10.53)	5.05 (0.66–38.49)
2010	1.05 (0.41–2.69)	23.73 (9.54–59.03)[†]	1.96 (0.79–4.9)	1.16 (0.13–10.09)	4.67 (0.61–35.69)
Cancer	1.13 (0.91–1.4)	-	0.91 (0.74–1.12)	0.87 (0.51–1.48)	0.8 (0.61–1.05)

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Outcomes: transfusion, harvesting of 12+ lymph nodes (LN) for cancer patients, wound infection, in-hospital death, and composite adverse event (CAE). Each of the odds ratios listed is adjusted for other covariates in the left column of the table (blank space indicates that the covariate was not included in the model).

*CAE was defined by composite of operative interventions and deaths. Composite of operative interventions were defined as an inhospital adverse event that resulted in an unplanned postoperative procedure including a return to the operating room for a formation of a new ostomy, revision of the anastomosis, re-exploration/washout, evisceration, operation for postoperative bleeding, or irrigation and drainage of an intra-abdominal abscess, or a non-operative percutaneous drain placement, and/or operative drain placement.

†95% confidence intervals that indicate significance at the 5% level.

‡Referent groups for above variables are as follows: female for sex, comorbidity index of 0 for Charlson's comorbidity index, and year 2005 for referent year.

Table 4

Adjusted Logistic Regression Analysis of Variables Associated with the Use of Laparoscopy in Colorectal Operations

	Laparoscopic surgery (OR, 95% CI)			
	Indication for operation		Type of operation	
	Diverticular disease vs all other non-oncologic indications, n=2,706	**Cancer vs all other indications, n=4,601**	**Right hemocolectomy vs all other types of operations, n=4,601**	**Low anterior resection vs all other types of operations, n=4,601**
Indication for surgery: diverticular disease	2.02 (1.7–2.41)*	-	-	-
Indication for surgery: cancer	-	0.99 (0.86–1.13)	-	-
Type of operation: right hemicolectomy	-	-	1.35 (1.19–1.54)*	-
Type of operation: low anterior resection†	-	-	-	0.81 (0.71–0.93)*
Age	1.0 (0.99–1.0)	0.99 (0.99–1.0)	1.0 (0.99–1.0)	1.0 (0.99–1.0)
Male sex†	1.09 (0.92–1.29)	1.14 (1.01–1.29)*	1.14 (1.01–1.29)*	1.13 (0.99–1.29)
Albumin	1.42 (1.25–1.6)*	1.36 (1.23–1.49)*	1.36 (1.24–1.5)*	1.38 (1.25–1.51)*
Diabetes	0.91 (0.66–1.26)	0.88 (0.7–1.11)	0.87 (0.69–1.1)	0.87 (0.69–1.1)
Body mass index	1.0 (0.99–1.01)	1.0 (0.99–1.01)	1.0 (0.99–1.01)	1.0 (0.99–1.01)
Charlson comorbidity index†				
1	0.86 (0.67–1.1)	0.96 (0.8–1.16)	0.97 (0.77–1.17)	0.96 (0.8–1.16)
2	1.15 (0.76–1.75)	1.04 (0.76–1.41)	1.04 (0.77–1.42)	1.03 (0.76–1.4)
3+	1.12 (0.56–2.26)	1.15 (0.68–1.93)	1.16 (0.69–1.96)	1.14 (0.68–1.93)
Year†				
2006	1.3 (0.76–5.3)	0.9 (0.42–1.93)	0.86 (0.4–1.84)	0.94 (0.44–2.0)
2007	1.65 (0.38–2.7)	1.23 (0.59–2.55)	1.18 (0.64–2.72)	1.28 (0.62–2.66)
2008	2.09 (0.48–3.21)	1.93 (0.94–3.93)	1.87 (0.92–3.8)	2.03 (0.99–4.14)
2009	2.05 (0.5–3.31)	1.91 (0.94–3.87)	1.87 (0.92–3.78)	2.02 (0.99–4.09)

	Laparoscopic surgery (OR, 95% CI)			
	Indication for operation		Type of operation	
	Diverticular disease vs all other non-oncologic indications, n=2,706	**Cancer vs all other indications, n=4,601**	**Right hemocolectomy vs all other types of operations, n=4,601**	**Low anterior resection vs all other types of operations, n=4,601**
2010	2.71 (0.41–2.69)	2.33 (1.15–4.72) *	2.27 (1.13–4.58) *	2.47 (1.22–4.99) *
Cancer	-	-	0.95 (0.83–1.09)	0.98 (0.86–1.12)
Hospital bed ≥ 200	0.58 (0.45–0.74) *	0.67 (0.56–0.8) *	0.68 (0.57–0.81) *	0.68 (0.57–0.81) *
Urban location of hospital	2.44 (1.6–3.71) *	2.7 (1.98–3.69) *	2.66 (1.94–3.64) *	2.74 (2.0–3.75) *

Each of the following odds ratio listed is adjusted for all other covariates on the left column of the table (blank space indicates that the covariate was not included in the model).

*95% confidence intervals that indicate significance at the 5% level.

†Referent groups for above variables are as follows: female for sex, comorbidity index of 0 for Charlson's comorbidity index, and year 2005 for referent year.