Rethinking elective colectomy for diverticulitis in Washington State

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ABSTRACT

The management of diverticulitis is becoming an increasingly important problem, with an estimated 1.5 million inpatient days and 300,000 admissions each year.[1-3] While 10-20% of people admitted to the hospital for diverticulitis undergo emergency resection, [4,5] regardless of whether or not patients undergo surgery during initial presentation, they remain at lifetime risk for recurrent episodes and hospitalizations. Surgeons play an integral role in counseling patients on the risks of recurrence versus the risks of an operation, adhering to the premise that elective, "prophylactic" colectomy can prevent future episodes of diverticulitis and emergency colostomy.[6,7] Accordingly, diverticulitis is one of the leading indications for elective colon resection.[8,9]

Over the last decade, however, the relationship between elective and emergency surgery has come into question. With most emergency resections being performed in patients without a prior hospitalization,[4,5,10] it has become apparent that diverticulitis recurrences are a poor predictor of need for future emergency operation at the population level. Furthermore, the observed increase in the rates of elective colectomy has not correlated with decreases in emergency colectomy.[11] In light of these gaps in evidence, a number of international professional societies have indicated that surgery should no longer be performed based on the number of prior episodes of diverticulitis. [1,6,12,13]

This thesis encapsulates three studies that address the evidence gaps about elective colectomy for diverticulitis by assessing patterns of elective colectomy at the population level in Washington State. The first study describes the relationship between the incidence in elective and emergency colectomy over the last two and half decades.[14] The second study considers surgeon-reported indications for elective colectomy across the majority of hospitals in Washington.[15] The third study explores the impact of diverticulitis episode number on successful completion of laparoscopic surgery, the dominant operative approach used for diverticulitis in the modern era. [16] Together, these studies provide contemporary epidemiologic evidence for patterns in treatment of diverticulitis at a population-level, and motivate future work to guide decision-making related to elective surgery for this disease.

STUDY 1: ***The Impact of Elective Colon Resection on Rates of Emergency Surgery for Diverticulitis***[14]

ABSTRACT

Objective: To determine the impact of elective colectomy on emergency diverticulitis surgery at the population level.

Background: Current recommendations suggest avoiding elective colon resection for uncomplicated diverticulitis because of uncertain effectiveness at reducing recurrence and emergency surgery. The influence of these recommendations on use of elective colectomy or rates of emergency surgery remains undetermined.

Methods: A retrospective cohort study using a statewide hospital discharge database identified all patients admitted for diverticulitis in Washington State (1987–2012). Sex and age-adjusted rates (standardized to the 2000 state census) of admissions, elective and emergency/urgent surgical and percutaneous interventions for diverticulitis were calculated and temporal changes assessed.

Results: 84,313 patients (mean age 63.3 years and 58.9% female) were hospitalized for diverticulitis (72.2% emergent/urgent). Elective colectomy increased from 7.9 to 17.2/100,000 people ($p<0.001$), rising fastest since 2000. Emergency/urgent colectomy increased from 7.1 to 10.2 per 100,000 ($p<0.001$), non-elective percutaneous interventions increased from 0.1 to 3.7 per 100,000 ($p=0.04$) and the frequency of emergency/urgent admissions (with or without a resection) increased from 34.0 to 85.0 per 100,000 ($p<0.001$). In 2012, 47.5% of elective resections were performed laparoscopically compared to 17.5% in 2008 (when the code was introduced).

Conclusions: The elective colectomy rate for diverticulitis more than doubled, without a decrease in emergency surgery, percutaneous interventions or admissions for diverticulitis. This may reflect changes in thresholds for elective surgery and/or an increase in the frequency or severity of the disease. These trends do not support the practice of elective colectomy to prevent emergency surgery.

INTRODUCTION

Each year in the United States 300,000 admissions and 1.5 million days of inpatient care are related to the management of acute diverticulitis. [2,3,11,17] While most episodes resolve with antibiotics alone, [6] 10-20% of patients will have an emergency colectomy, often including a colostomy, at their initial presentation and all patients remain at lifetime risk for recurrent episodes. [4,5] Diverticulitis is one of the most common reasons for emergency colostomy [5] and the leading reason for elective colon resection. [7,9]

There has been a long-held belief that elective, "prophylactic" colectomy can prevent future episodes of diverticulitis and emergency colostomy. [6,7] More recent evidence, however, suggests that the rate of diverticulitis recurrence after resection (5-11%)

[4] is similar to the rate of recurrent hospitalized events (4-13%) for those who do not have elective resection. [10] Modeled analyses have shown little value to prophylactic colectomy and observed changes in the rate of elective colectomy do not appear to correlate with decreases in emergency colectomy. [11] Recent studies have shown that the risk of emergency colectomy is greatest at the initial presentation with diverticulitis, with 80-90% of emergency procedures being performed in patients without a prior hospitalization. [4,10,18] Several professional organizations have used this evidence to shift their recommendations away from early prophylactic resection (after one or two documented episodes) until after multiple (3 or more) episodes. [6,12,13] The most recent American Society of Colon and Rectal Surgeons (ASCRS) guidelines[1] now actually advise against routine elective resection for uncomplicated diverticulitis. Despite these cautions, a recent series of studies of the use of elective resection for diverticulitis from 1998 to 2007 found it increased more than 50%.[11,17,19] These studies have suggested that the pace of growth is related to the wide uptake of laparoscopic approaches for colectomy, rather than changes in the disease. [19]

Studies evaluating trends in elective colectomy have either been limited by short study periods [11,17,19] or have drawn conclusions based on proportions of elective procedures for diverticulitis among all colectomy procedures, rather than rates of elective colectomy in a population at risk for disease. [20] A focus on proportions rather than on the rates of colectomy does not account for changes in the population

at risk or changes in the use of emergency colectomy. A recent meta-analysis [4] points to gaps in our understanding of the association between elective resection and prevention of subsequent complications. The purpose of this study was to characterize trends in the incidence of elective colectomy for diverticulitis in an entire state's "at risk" population over a 26-year time period, encompassing periods before and after laparoscopy was introduced. We sought to evaluate whether changes in the incidence of elective colectomy were associated with rates of emergency colectomy and factors that might be associated with varying rates of elective colectomy.

METHODS

This study was exempted from human subjects review by agreement of the University of Washington Human Subject Review Committee and the Washington State Department of Social and Health Services Institutional Review Board.

Data Source

A retrospective cohort study was conducted using a statewide, population-based hospital discharge database. Data were obtained from the Washington State Comprehensive Hospital Abstract Reporting System (CHARS) database. This dataset was derived from all public and private hospitals in Washington State, excluding Veterans Affairs (VA) and U.S. military hospitals. Error resulting from missing VA and military hospital patients was recognized but assumed to be stable over time. The dataset contains demographic variables, admission and discharge administrative details, payer status, Ninth Revision of the International Classification of Diseases (ICD-9) procedure and diagnosis codes, and coded hospital identifiers. United States census bureau data for yearly state population estimates were used for population-based analyses. Surgeon volume per county was estimated using unique NPI numbers appearing as operating surgeon in the database.

Study population

Inclusion into the cohort was defined by identifying all CHARS reports for ICD9 diagnostic codes for diverticulitis (see **Appendix 1**). We excluded patients under the age of 18. We excluded

hospital records that came from trauma admissions. A modified Charlson co-morbidity index was calculated for each patient based on ICD-9 diagnostic codes. [21]

Variable Definition

The administrative designation of admission type was used to classify hospitalizations. Patients whose initial admission was characterized as not-elective (in other words, urgent or emergent per their discharge records) were included in the analysis. We identified those admissions having a concurrent colectomy code, open or laparoscopic, and those having percutaneous drainage performed based on the ICD9 codes listed in the Appendix. These codes were compiled from a non-systematic literature review of studies using administrative data to describe diverticulitis trends. [10,11,19,22] Patients who underwent colectomy procedures during their admission for diverticulitis were defined to have surgically treated diverticulitis. ICD9 codes for laparoscopy became available in 2008 (**Appendix 1**). As in previously published studies, our definition of laparoscopic surgery included codes for laparoscopic exploration or lysis of adhesions when combined with a code for colectomy. [22]

Data Analysis

Because population-based frequencies are sensitive to changes in the underlying population at risk, yearly population-based frequencies of diverticulitis admissions and surgical procedures were also calculated. Employing the direct method, all data were standardized for sex and age using the 2000 population of Washington State as the reference. All population-based frequencies were reported as a frequency per 100,000 people adjusted for age and sex using the direct standardization method. A test for trend using regression (i.e., the P value for whether the coefficient for calendar year was significantly different from 0) was applied to the frequencies of diverticulitis admissions, emergency and elective colectomies, and percutaneous interventions. The cohort was also divided into 5-year periods and demographic characteristics and treatment patterns were compared in each time period. County-specific rates were calculated for 2010, the year with the most current census demographic data, to offer a current estimate of prevalence of elective colectomy in those counties. Statistical analysis was performed using STATA statistical analysis software, version 13 (STATA Corp, College Station, TX).

Statewide variation

To evaluate for variation in practice within our state, we determined age- and sex- adjusted rates for admission and colectomy per county in Washington State. CHARS records reflect county of residence of the patient, not necessarily the county where they received their care. To account for fluctuations in rates of smaller counties, we focused our analysis on the 12 counties with a population of >100,000 people per the 2010 census. The number of surgeons practicing in each county was derived from unique operating physician identifier codes recorded in the discharge record.

RESULTS

There were 84,313 hospitalizations for diverticulitis, including 26,308 admissions with colon resections. The average age was 63.3 and decreased from 67.4 to 62.5 ($p<0.001$) (**Table 1.1**) over the study period.

The age- and sex- standardized incidence of non-elective hospitalization for diverticulitis was 53.5 per 100,000 people for the entire period but increased dramatically from 34.0 to 85.0($p<0.001$).The incidence of elective colectomy was 13.2 per 100,000 people for the entire period but increased from 7.9 to 17.2($p<0.001$),rising fastest since 1995(**Figure 1.1**). The incidence of non-elective colectomy was 9.9 per 100,000 people for the entire period and increased slightly over the period, from 7.2 to 10.3($p<0.001$).

The use of percutaneous drainage during non-elective admission increased from 0.1% to 3.7% ($p=0.04$) and the proportion of non-elective hospitalization in which an emergency colectomy was performed decreased from 21.1% to 12.1% ($p<0.001$).

Laparoscopic codes became available in 2008. Since that time, the proportion of elective cases described as laparoscopic increased from 17.5% in 2008 to 47.5% in 2012 ($p<0.001$).

Among the 12 counties with larger populations (>100,000 people), the mean rate for elective colectomy was 13.4 per 100,000 people in 2010. There was significant variability in the age- and sex-adjusted rates of elective colectomy, with the rate of elective colectomy varying 8.9 to 17.1. Notably, even the rates in adjacent counties such as counties D and F had two-fold differences (**Figure 1.2**).

Counties with increased numbers of surgeons did not have an increased rate of age- and sex-standardized elective colectomy (p=0.9).

DISCUSSION

In Washington State, over the last 26 years the age- and sex-adjusted incidence of elective colectomy for diverticulitis more than doubled. This increase was not accompanied by a decrease in emergency colon resection, percutaneous interventions or admissions for diverticulitis. These trends occurred in parallel to evolving professional recommendations suggesting delaying elective colectomy for diverticulitis surgery and may highlight an important gap between recommendations and current practice. It is possible that these observations may be related to the availability of laparoscopic techniques and a lowering of the threshold for recommending resection, greater patient acceptance of the less invasive approach, a rise in more symptomatic disease that is prompting the broader use of elective colectomy or several other factors that cannot be evaluated using administrative claims data. What appears to be clear is that the growing use of elective colectomy has not decreased the use of emergency surgery on a population level.

The changes in professional guidelines over the last decade have resulted in a "moving target" related to recommendations for elective surgery for diverticulitis (**Table 1.2**). Long-standing recommendations from ASCRS based on data from the 1960s were that elective resection be considered after the second episode of diverticulitis [23-25] and in patients under 50 years of age, after the first episode. [23,25,26] Studies in the last decade challenged this thinking citing a 5-11% risk of recurrence after resection [4,13] and demonstrating a similar, small rate of recurrent hospitalized events (4-13%) for those who do not have elective resection. [10] Elective resection also carries the risk (1-3%) of "rescue colostomy" [12,27] for anastomotic failure. A decision analysis by our group [5] that considered all these parameters demonstrated that waiting until at least 4 recurrent hospitalized episodes-something that occurs in less than 5% of the population [10] -decreases the risk of colostomy, complications, and cost. [5] The ASCRS 2006 guidelines [6] incorporated these modeled data and recommend delaying surgery well beyond 1-2 episodes. The just released 2014 ASCRS guidelines "strongly advise" against early resection for

uncomplicated disease. [1] Similar advisory groups in Europe [12,13]suggest that elective surgery should not be tied to a specific number of events and have called for trials to assess the value of ever performing elective resection. [28,29] However, as a recently published systematic review in *JAMA* pointed out, the evidence behind all these existing guidelines is woefully inadequate and "there is a need for better population-level studies that address the fundamental epidemiology of the disease". [4]

There are several hypotheses to explain the apparent gap between the dramatic rise in elective colectomy found in our study and professional guidelines which call for delay and even avoiding surgical resection of diverticulitis. First, it is possible that during the last several decades, despite evolving guidelines, the threshold for offering elective colectomy has not changed, and instead the population of patients who have the disease is increasing. To our knowledge, there has been no other evidence of such rapid growth of the condition (e.g colonoscopic detection of diverticulosis) over so short a period, particularly since 2000. It may be that some of the apparent increased incidence of hospitalization for diverticulitis shown by our study and others [11,17-19] is attributable to the greater use of computed tomography, identifying diverticulitis in patients who formerly would have been diagnosed with abdominal pain "not otherwise specified" or some other condition. [30,31]While this might explain some of the increase in non-elective admissions for diverticulitis, it is unlikely that there was such a large group of previously misdiagnosed patients admitted to hospitals in the 1990s, when CT scans were also widely available.

Another possibility is that the severity of diverticulitis has been increasing, and surgeons may be performing more elective procedures on patients who more complicated disease. This theory was popularized by advocates for early resection in younger patients (described as age < 50 years) [7,26,32] due to the belief that younger people were more likely to have severe recurrences requiring emergency surgery. [10,23,33,34] However, recent studies offer conflicting evidence about whether diverticulitis in the young is a more virulent entity, [34-37] and the newest ASCRS guidelines do not recommend resection in younger patients either. Severity of disease is difficult to measure with claims data, because codes for abscess, peritonitis and perforation are often secondary and inconsistently recorded. Thus, our study and others [20]

have tried to understand patterns of severity by evaluating the proportion of non-elective admissions having emergency surgery, which has actually decreased considerably (from 20 to 10% in our study). Plausible explanations for the decreased proportion requiring emergency operation include better management with percutaneous interventions, [18,20] better classification of disease severity with improved imaging, [38] a higher threshold for offering emergency operation [4] or perhaps a shift from offering emergency surgery to a delayed elective surgery. [4] The approach of delaying surgery beyond the first hospitalization may be unsupported however given that a prior report on a subset of this WA State population, [5,15] the most recent ASCRS guidelines, [1] and a recent systemic review, [4] have highlighted that 80-90% of patients who have a complications requiring emergency surgery do so during their initial hospitalization for diverticulitis. Based on these constellations of findings, offering elective surgery to prevent future emergency surgery is no longer supported.

An alternate explanation for the findings in this study may be that surgeons' threshold for offering elective colectomy for diverticulitis is lower now than in the past and/or that a patients' willingness to undergo elective resection has changed. It has been speculated that the growth in elective resection has more to do with the availability of laparoscopy than any changes in the disease itself. [19] Laparoscopic techniques for colorectal surgery have grown in popularity since they were introduced in 1991. [39] Widespread uptake did not come until the early 2000s when training programs began incorporating it and several randomized trials of laparoscopy for colon cancer were published. [40,41] Recent studies suggest that laparoscopic colectomy improves outcomes through lower morbidity, including lower rates of wound infection and quicker discharge from the hospital. [41,42]Nationally, there is growing use of laparoscopic colon surgery (LCS), and when measured in 2012 at most hospitals in Washington State, 60%of all colectomies for diverticulitis were performed laparoscopically. [15] Hospitals that adopted laparoscopy at a faster pace in Washington State had much faster growth in the use of elective resection for diverticulitis and a surge in right-sided resections, previously an uncommon procedure. [43] This growth in the use of elective resection has been shown to be even greater among younger patients [11,17] the majority of which had LCS. Another suggestion of the association between the availability of LCS and

the rise of elective resection is that countries where there is greater use of laparoscopic resection have higher rates of elective surgery for diverticulitis. [22,44] Since these countries are assumed to have similar incidence of disease, this has reinforced speculation that the threshold to recommend and undergo surgery has been lowered by the availability of LCS, similar to what occurred with the introduction of laparoscopic gall bladder surgery in the late 1980s. [45,46]

The variation between counties in our study may reflect a combination of these hypotheses. We focused on the most populated counties to minimize fluctuation that would be seen with low-population counties. Still, we found no association between age- and sex-adjusted rates of procedures, number of surgeons, and county of residence, suggesting that the lower incidence in some counties is not explained by an 'access to care' barrier. Rather, it implies that variation in surgeon practice for recommending resection may be the driver of surgery in higher incidence counties.

Our study has several limitations. Laparoscopy as a billing code first appeared in 1992 but it was not until 2008 that a code for laparoscopic colon resection was developed. Before 2008, there was variable coding for "unlisted laparoscopy" or "diagnostic laparoscopy" (**Appendix 1**) associated with colectomy procedures. Using this method for identifying potentially laparoscopic procedures prior to 2008, we found rates varying between 0 and 5%. For this reason we could not assess the impact of laparoscopic surgery on the trends in elective colectomy. Since the introduction of laparoscopic colectomy codes in 2008, we saw more consistent coding with the proportion of cases using laparoscopy increasing from 17.5% to 47.5% ($p<0.001$) and no difference in change in rates of elective procedures between counties that were above or below the median proportion of cases performed laparoscopically. Another limitation is that a database based on discharge records may miss important trends in the population of patients with diverticulitis who are not hospitalized, and it has been estimated that as much as 60% of all diverticulitis care takes place in the outpatient setting. [47] This limitation is not likely to effect the observation of surgery because none of that outpatient care is expected to include colectomy. Additionally, we could not evaluate the indications for surgical therapy. Granularity about episode number, complicated disease, or burden on quality of life is not available through hospital discharge

records, making it impossible to determine, for instance, whether increasing rates of operations in younger patients reflects more severe disease in this group, whether the impact of diverticulitis on their lives and quality of life is greater, and/or if clinicians are making decisions about invasive treatments based on their younger patients' comparatively good health or longer life expectancy. Another limitation is reliance on discharge record diagnostic coding. Inconsistencies in coding practices or new code adoption, such as laparoscopic procedures, might explain differences in rates reported in our study as compared to those from sources such as operative reports [15] or chart review. [22,44]

These population-level trends appear to highlight an important gap between guidelines and practice, and indicate the need for better data to describe the motivation behind the use of surgical therapy for diverticulitis. In Washington State, the Surgical Care and Outcomes Assessment Program (SCOAP), a state-wide collaborative of hospitals focused on quality improvement in surgical care, started a benchmarking and educational campaign focused on indications for colectomy for diverticulitis. Each quarter, hospital use of elective surgery and appropriateness of indications is reported, compared to others in the network. Since 2010, elective colectomies at SCOAP hospitals, which perform over 80% of the colectomy volume in the state, have leveled without an increase in emergency surgery, [15] further substantiating this study's findings of a disconnect between elective colectomy at preventing subsequent emergency.

Our study shows that over the past 26 years in Washington State, rates of elective colectomy for diverticulitis have more than doubled, and this dramatic increase in elective surgery was not accompanied by a decrease in the rate of emergency surgery, percutaneous interventions or admissions for diverticulitis. Given that 80-90% of emergency surgery happens at the first episode of diverticulitis, the findings in this study suggest that the practice of routine elective colectomy does not prevent future emergency surgery. Accountable care organizations, healthcare payers, and those making strategic decisions about population health should consider this evidence when developing policies related to diverticulitis.

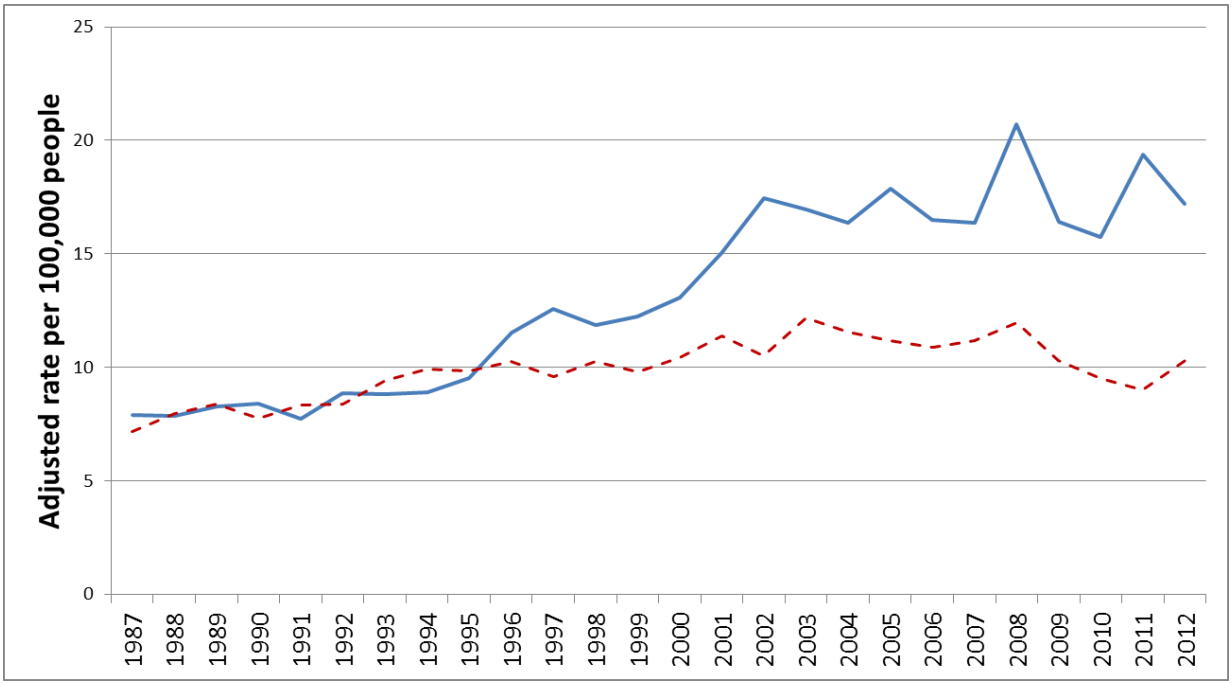
TABLES AND FIGURES

Table 1.1. Incidence of admissions and surgery for diverticulitis in Washington State between 1987 and 2012

	Overall	1987-1991	1992-1996	1997-2001	2002-2006	2007-2012	p-value*
Age	63.3	66.4	65.2	63.8	61.6	62.1	p<0.001
Female (%)	58.9	62.5	60.7	58.1	57.8	57.9	p<0.001
Charlson Comorbidity Index (%)							p<0.001
0	64.8	71.2	66.3	63.6	64.4	62.5	
1	22.5	19.4	21.7	22.9	23.7	23.2	
2	8.2	6.3	7.9	8.9	7.8	9.1	
3+	4.5	3.1	4.2	4.6	4.2	5.2	
Rate of non-elective admission (per 100,000 people)**	53.5	35.2	41.9	50.1	59.6	76	p<0.001
Rate of non-elective colectomy (per 100,000 people)**	9.9	7.9	9.6	10.3	11.2	10.4	p<0.001
Colectomy during non-elective admission (%)	18.5	22.5	22.8	20.5	18.9	13.6	p<0.001
Rate of percutaneous drain during non-elective admission (per 100,000 people)**	0.7	0.1	0.3	1	1	1.2	p=0.04
Rate of elective colectomy (per 100,000 people)**	13.2	8	9.5	13	17	17.6	p<0.001
Proportion of elective cases performed laparoscopically	7.65	0	0.9	2.5	2.2	21.5	p<0.001

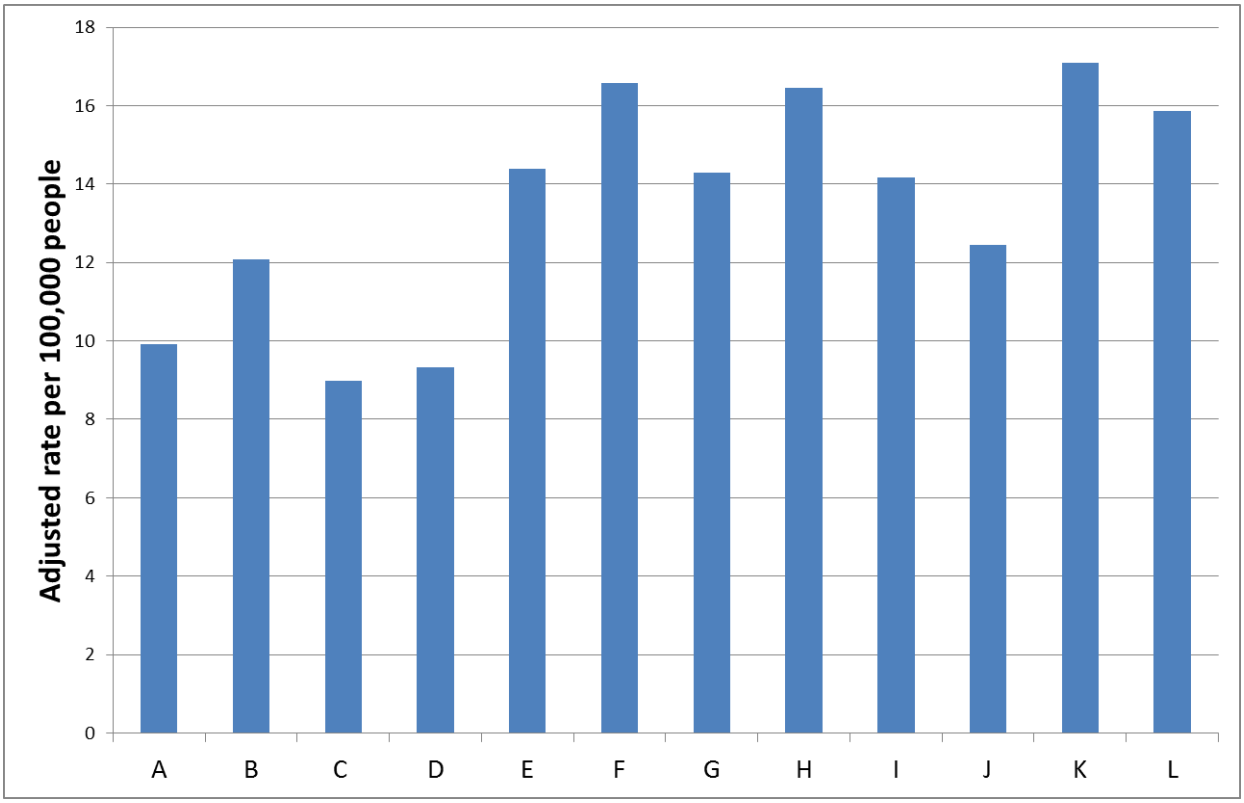
** p-values calculated as test of trend using yearly data from 1987-2012*
*** rates per 100,000 people are age- and sex- adjusted to Washington State's population in 2000*

Figure 1.1. Rates of Elective and Non-elective colectomy 1987-2012



Age- and sex-adjusted rates (to the 2000 state census population) of elective colectomy (solid line) and non-elective colectomy (dashed line) over 26 years in Washington State.

Figure 1.2. Adjusted rate of elective colectomy in counties with more than 100,000 people



The most contemporary age- and sex-adjusted rates (to the 2010 state census population) of elective colectomy vary nearly two-fold in the 12 largest counties (all with more than 100,000 people) in Washington State, even in counties which are geographically adjacent.

Table 1.2. ASCRS Recommendations for surgery following recovery from acute diverticulitis

Year Elective surgery after…	**1995** *Roberts et al* [48]	**2000** *Wong et al* [7]	**2006** *Rafferty et al* [6]	**2014** *Feingold et al* [1]
Uncomplicated diverticulitis	After two attacks of uncomplicated diverticulitis, resection is recommended. Although it has been the practice to recommend elective resection in the young patient after one well-documented episode of uncomplicated diverticulitis, the natural history of diverticular disease in the young patient has not been clearly defined.	After two attacks of uncomplicated diverticulitis, resection is commonly recommended. Although some surgeons recommend elective resection in the young patient after one well-documented episode of uncomplicated diverticulitis, this tenet remains controversial, because the natural history of diverticular disease in the young patient has not been clearly defined.	The decision to recommend elective sigmoid colectomy after recovery from acute diverticulitis should be made on a case-by-case basis (IIIB). The number of attacks of uncomplicated diverticulitis is not necessarily an overriding factor in defining the appropriateness of surgery. There is no clear consensus regarding whether younger patients (younger than aged 50 years) treated for diverticulitis are at increased risk of complications or recurrent attacks.	The decision to recommend elective sigmoid colectomy after recovery from uncomplicated acute diverticulitis should be individualized (1B). The literature demonstrates that patients with more than 2 episodes are not at an increased risk for morbidity and mortality in comparison with patients who have had fewer episodes. The practice of recommending elective colectomy to prevent a future recurrence is not supported by this literature and should be discouraged. Routine elective resection based on young age (<50 years) is no longer recommended. Strong recommendation based on low-quality evidence (1C).
Complicated diverticulitis	Resection is recommended for patients with diverticulitis after one event.	Resection may be recommended for patients with complicated diverticulitis after a single attack.	Elective colon resection should typically be advised if an episode of complicated diverticulitis is treated nonoperatively (IIIB).	Elective colectomy should typically be considered after the patient recovers from an episode of complicated diverticulitis. Strong recommendation based on moderate-quality evidence (1B).

STUDY 2: Addressing the Appropriateness of Elective Colon Resection for Diverticulitis [15]

ABSTRACT

Objective: To assess the reported indications for elective colon resection for diverticulitis and concordance with professional guidelines

Background: Despite modern professional guidelines recommending delay in elective colon resection beyond 2 episodes of uncomplicated diverticulitis, the incidence of elective colectomy has increased dramatically in the last 2 decades. Whether surgeons have changed their threshold for recommending a surgical intervention is unknown. In 2010, Washington State's Surgical Care and Outcomes Assessment Program initiated a benchmarking and education initiative related to the indications for colon resection.

Methods: Prospective cohort study evaluating indications from chronic complications (fistula, stricture, bleeding) or number of previously treated diverticulitis episodes for patients undergoing elective colectomy at one of 49 participating hospitals (2010–2013).

Results: Among 2724 patients (58.7 ± 13 years, 46% male), 29.4% had a chronic complication indication (15.6% fistula, 7.4% stricture, 3.0% bleeding, 5.8% other). For the 70.5% with an episode-based indication, 39.4% had ≤ 2 episodes, 56.5% had 3–10 episodes, and 4.1% had > 10 episodes. Thirty-one percent failed to meet indications for either a chronic complication or ≥ 3 episodes. Over the four years, the proportion with a ≥ 3 episode indication increased from 36.6% to 52.7% ($p<0.001$), while those that failed to meet either clinical or episode-based indications decreased from 38.4% to 26.4% ($p<0.001$). The annual rate of emergency resections did not increase significantly, varying from 5.6 to 5.9 per year ($p=0.81$).

Conclusions: Adherence to a ≥3 episode guideline for elective colectomy increased concurrent with a benchmarking and peer-to-peer messaging initiative. Improving adherence to professional guidelines related to appropriate care is critical, and can be facilitated by quality improvement collaboratives.

INTRODUCTION

Acute diverticulitis is one of the most common indications for hospitalization related to the gastrointestinal (GI) tract, and a leading indication for both elective colon resection and emergency colostomy. [2,3,5,10] For over 50 years surgeons have been trained to recommend elective, "prophylactic" colectomy after two episodes of uncomplicated diverticulitis, and even following one episode for those younger than the age of 50, in presumed hope of reducing the risk of colostomy. [23-25] Contemporary data have brought into question the preventive role of elective surgery for diverticulitis and highlighted the very low risk of emergency colectomy in patients undergoing non-operative management. In the last 10 years, several surgical societies have produced guidelines which have recommended delaying elective resection until after more than 2 episodes. [6,12,13] The most recent American Society of Colon and Rectal Surgeons (ASCRS) guidelines "strongly advise" against elective resection for uncomplicated diverticulitis and consider multiple episodes as an indication only for those with "complicated disease". [1] Surprisingly, despite these recommendations, the use of elective surgery appears to be increasing faster than the incidence of diverticulitis, [11,17,19] with a recent statewide analysis showing a 3-fold increase in the incidence of elective colectomy for diverticulitis during the laparoscopic era.[14]

Given the escalating costs of care and a focus on value-added interventions, there has been increasing interest in establishing appropriateness criteria for many surgical procedures. [49-53] Assessing compliance with appropriateness of care recommendations, such as delaying elective resection for diverticulitis, has been problematic because detailed information about the indications for surgery is not commonly gathered by existing registries. In 2010, Washington State's Surgical Care and Outcomes Assessment Program (SCOAP) began surveillance, benchmarking, and education related to the indications for colon resection related to diverticulitis. The aim of this study was to assess the clinician-reported indications for elective colectomy and describe trends in the number of prior episodes of diverticulitis, concurrent to SCOAP's messaging and benchmarking initiative related to established guidelines.

METHODS

Study Design

Consecutive patients who underwent elective colon resection following recovery from diverticulitis between January 1, 2010 to December 31, 2013 in 49 Washington State hospitals that participate in SCOAP were included in the primary cohort. This study was exempted from human subjects review by agreement of the University of Washington Human Subject Review Committee and Washington State Department of Health. The Comparative Effectiveness Research Translation Network (CERTAIN) provided research and analytic support to SCOAP. [54] Patients undergoing emergent colectomy for diverticulitis were included for descriptive statistical comparison and for measuring trends over the time course of the study alone.

Data Sources and Definitions

Sociodemographic and clinical characteristics were extracted from inpatient medical records by trained chart abstractors at each clinical site. Operative details, including elective or emergent nature of the operation and the indications for surgery, were abstracted from operative reports and clinical records. Standardized dictation guides were supplied to all clinicians to improve the ability of abstractors to accurately record the indications for each procedure. (**Appendix 2**). SCOAP metrics and data dictionary are publicly available (http://www.SCOAP.org). A modified Charlson comorbidity index for each patient was calculated. [21]

Indications

Clinical and episode-based indications were included in the SCOAP data collection platform in 2010. These definitions were created based on review of existing evidence and guidelines by an expert panel of colorectal and general surgeons across Washington State. Chronic complication indications included gastrointestinal bleeding (GIB), stricture, and fistula. In addition, starting in 2011 the category 'other' was added to help capture unmeasured clinical indications. The total numbers of prior episodes of diverticulitis were derived from clinical records and surgeons' dictations. Prior episodes were initially captured as a continuous variable, but were converted to categories as 1, 2, 3–10, and >10 after 2010.

Performance Benchmarking and Messaging Related to Guidelines

Beginning in 2011, participating SCOAP hospitals were provided feedback to disseminate to their surgeons about the proportion of their procedures that either failed to indicate the presence of a clinical indication, or were absent a clinical indication, or had 2 or fewer prior episodes of diverticulitis. Comparative data from all sites was made available in each report, and a series of presentations and alerts about the benchmarking program and available guidelines [6,27,55] related to indications for elective surgery in diverticulitis were distributed through newsletters, web-based messages, regional and statewide meetings, and through an informal peer network. This included broad dissemination of the 2006 ASCRS guidelines, [6] as they were the most up-to-date available at that time.

Statistical Analysis

Patient characteristics were summarized using frequency distributions for categorical variables, and mean (SD) for continuous variables. Descriptive and comparative statistics were applied using STATA version 13 (STATA Corp, College Station, Tex). Categorical variables were compared using Pearson $\chi 2$ statistic and change over time is reported using a test of trend. A P value of less than .05 was considered statistically significant.

RESULTS

Between 2010 and 2013, there were 3,613 colectomies performed for a diverticulitis-related indication and 75.4% were elective (n=2,724).

Characteristics

The mean age of patients having elective colectomy for diverticulitis was 58.7 ±13 years, with 24.1% of the cohort being younger than 50 years. Those younger than 50 were more likely to be male (62.4% vs 41.6%, $p<0.001$) and have lower Charlson comorbidity scores ($p<0.001$) (**Table 2.1**).

Indications

Data on the underlying indication for resection was missing in 28.1% over the entire course of the study and was similar across age groups. Of those with complete data and undergoing an elective

resection, 31.3% did not report a chronic complication indication or meet ≥ 3 episode threshold. A chronic complication was the indication for elective surgery in 29.4% of patients (15.6% fistula, 7.4% stricture, 3.0% bleeding, 5.8% other). The proportion of those with a chronic complication indication for operation was lower in younger patients, (17.3% in those < 50 years versus 33.4% in those 50 years and older, p<0.001). Of those having an episode-number based indication, 39.4% had ≤ 2 episodes, 56.5% had 3–10 episodes, and 4.1% had > 10 episodes. There was no difference between younger and older age groups in having elective surgery after < 3 episodes, which occurred in 47.1% of younger and 49.7% of older patients (p=0.35). Laparoscopic surgery was used in 59.5% of cases. Younger patients had laparoscopy in 64.6% of cases versus 57.9% in older patients (p=0.002).

Temporal Trends

The proportion of those with chronic complication indications (GIB, fistula, stricture and other) remained unchanged over the period of the study (p=0.69) (**Table 2.2**). Of patients having elective colectomy based on the number of prior episodes, the proportion with ≥3episodes of diverticulitis increased from 36.6% to 52.7% (p<0.001) over the three years studied. In patients younger than 50 years, the proportion of elective resections meeting chronic complication- or 3+ episode-based indications increased from 54.3 to 69.8%, (p=0.001) while in those who were 50 or older this proportion increased from 64.3% to 74.8% (p=0.003) (**Figure 2.1**). In the whole cohort, the proportion that did not meet either complication- or ≥ 3 episode-based indications decreased from 38.4% to 26.4% (p<0.001). Over the study period, the proportion of patients with missing indication data decreased from 38.1% to 21.6% (p<0.001)

Impact on Rates of Emergency and Elective Colectomy

There were 25 hospitals where > 10 colectomies for diverticulitis per year were performed. We limited an analysis of trends in case volume per hospital to these facilities. The yearly rate of non-elective cases did not change significantly (5.6 to 5.9 per year, p=0.81) and the rate of elective colectomy remained stable (22.7 to 22.4 per year, p=0.95).

DISCUSSION

In Washington State hospitals, 68.7% of all elective colon resections with complete indications information for diverticulitis were guideline concordant with either a chronic complication or ≥ 3 episodes of prior diverticulitis as an indication. Nearly all hospitals in the state participate in SCOAP, which began tracking detailed information about the indications for diverticulitis-related colon resection in 2010. Surgeons at SCOAP hospitals are asked to include information about the indication for elective resection into the operative note using a standard dictation template (**Appendix 2**). Data fields include the number of episodes of diverticulitis (not specified as in-hospital or out-of-hospital) and non-episode based chronic complication indications (fistula, stricture, bleeding or other which includes persistent symptoms and other clinical conditions). In the year following the initiation of indication tracking, we implemented a formal component of the program where performance benchmarking, including quarterly reports of a site's missing data on indications, rates of < 3 episode indications and comparisons to average performance and best performers was delivered to every hospital. A mix of mailings, regional and statewide meetings, and peer-to-peer messaging occurred at least quarterly. Concurrent to this benchmarking, peer-to-peer messaging and education initiative about professional guidelines, the proportion of procedures not meeting the recommendations decreased by over a third, from 38.4% to 26.4% ($p<0.001$).

Surgeons have long been trained that elective surgery should be performed after 1-2 episodes of diverticulitis, in order to prevent potential complications including emergency colectomy and colostomy. More contemporary data have failed to demonstrate that this type of "preventative" surgery actually decreases the rate of emergency surgery at the population level. Most emergency colectomies for diverticulitis occur at the initial hospitalization [4,5] and the likelihood of recurrent hospitalization (5–13%) and emergency colostomy (<5%) are quite low for those who do not have elective resection. [10] Equally important is the finding that elective resection does not eliminate the risk of recurrent diverticulitis, with several studies demonstrating a 5–11% risk of recurrence after resection. [12,56,57] Elective resection also carries the risk (1–3%) of "rescue colostomy" [12,27] for anastomotic failure. A decision analysis by our group[5] which considered all these parameters demonstrated that if the recommendation for prophylactic

colectomy is delayed until at least 4 episodes hospitalized episodes—something that occurs in fewer than 5% of the population[10] — the risk of colostomy, complications, and cost is lowest. [5] The ASCRS 2006 guidelines [6] incorporated these modeled data and recommended delaying surgery beyond 2 episodes. The 2014 ASCRS guidelines now actually recommend against elective, prophylactic surgery for uncomplicated diverticulitis. [1] This is particularly relevant because despite the growing body of literature supporting delaying or avoiding elective resection, over the last decade the incidence of elective resection has increased more than 50%.[11,17,19] This rise occurred at a much faster pace than emergency colon resection, another marker of incident disease. [11,17]An extension of our group's prior evaluation of trends in admissions and elective resection in Washington State [18] confirm this remarkable growth in elective surgery and found a near tripling of its incidence over the past 26 years. [14]

For over 30 years there have been concerns that a significant proportion of interventional healthcare is performed in patients who do not meet the appropriate indications for the procedure, but the extent of this problem and whether it truly reflects unnecessary care have been contested. [58,59]The Commonwealth Fund estimates that 1 in 3 healthcare dollars is spent for healthcare that either doesn't improve health or is unnecessary based on surveys of patients and medical records. A series of cohort studies performed in the 1990s and repeated in the 2000s searched medical records and diagnostic images for evidence of standard indications for carotid endarterectomy, coronary artery bypass grafting and percutaneous revascularization and also found that 1 in 3 did not meet standard criteria. [60-62] In response, professional societies have increased their production of guidelines and appropriateness criteria. Insurance companies have developed a number of mechanisms to increase adherence to these appropriateness criteria including prior authorization and application of criteria as a condition of payment (e.g. Milliman criteria in spine surgery). [63,64] These approaches have had mixed effects in reducing rates of procedures that do not meet the designated criteria. [65] There has been much less experience with performance benchmarking and peer-to-peer messaging in addressing the question of appropriate care in surgery, and in making surgeons aware of adherence to established guidelines.

Our study shows that contemporaneous to SCOAP's performance benchmarking and education campaign related to the ASCRS guidelines, the proportion of elective surgery that did not meet episode or clinical indications decreased, with approximately 30% not meeting the recommendations overall. As the rates of surgery meeting indications increased, we did not find an increase in the rate of non-elective colectomies performed for diverticulitis.

One important challenge in promoting adherence to professional society recommendations has been the evolving definition of appropriate indications for diverticulitis surgery. For example, during the 14-year period over which the three most recent ASCRS Practice Parameters have been published, there have been evolving recommendations about indications for elective surgery from a soft recommendation in 2000, "after two attacks of uncomplicated diverticulitis, resection is commonly recommended," [7] to a more declarative statement in 2014 that also suggests individualization based on patient experience "the decision to recommend elective sigmoid colectomy after recovery from uncomplicated acute diverticulitis should be individualized". Encouraging adherence to guidelines that are in evolution or include individualization is problematic. It remains to be determined whether patient experience issues were a component of the indications for resection in the 5.8% of our cohort classified as having "other" reasons for resection or in the 30% who had an episode-based indication but were reported to have less than 3 episodes. None of the professional society guidelines currently define discrete measures of patient experience to assess whether a resection is appropriate for a given patient based on their experience with the condition. When determining if an elective colectomy is a reasonable option for a given patient surgeons occasionally encounter patients who do not meet the ASCRS recommendations but who have emotional distress or anxiety related to the possibility of an emergency, fear of travel, uncertainty about insurance and childcare coverage, intolerance of oral antibiotics or family history. Because guidelines for appropriate indications only vaguely refer to customizing recommendations based on patient experience, measurement of compliance with indications is challenging, and often not well received by surgeons who counter that they are meeting the patient's interest and that they should not be penalized because the guidelines do not include such potentially legitimate metrics. To address this, our group is pursuing

research on patient perspectives of the indications for surgery. Assessing which patient-centered metrics improve after resection may more completely capture what should be considered appropriate care. One interpretation of the current study is that even when surgeons are asked to report indications, the existing metrics do not apply to a significant proportion of cases. This may call into question how useful these metrics actually are in directing initiatives aimed at more value added care.

Concurrent to the SCOAP benchmarking initiative was the increased adoption of laparoscopy, which may affect the threshold to recommend and undergo surgery. A lowering of the threshold to recommend and undergo cholecystectomy in the late 1980s [45,46]resulted in a 30% increase in the incidence of that procedure. The availability of laparoscopy led to a change in recommendations favoring surgery after a single episode of biliary colic [66] and calls for prophylactic cholecystectomy in some populations. [67] Indeed, with 60% of all elective colon resections in this study performed laparoscopically, it remains to be determined whether the availability of laparoscopic surgery is lowering the threshold to offer and undergo resection.

Our study has several limitations. First, the SCOAP registry is procedural rather than disease-based, and we may be missing important trends occurring in the overall population with diverticulitis. We report trends in elective and emergency surgery as being stable but these trends should be interpreted cautiously as the study spans only four years, and other studies have pointed to increasing rates of elective surgery for diverticulitis. [11,17,19] Another limitation of this study is the substantial proportion of patients that have missing data. While we found no differences between those with and without indication data, this may limit the generalizability of our findings. It may also mean that our findings of increasing proportions of multiple-episode indications for elective colectomy simply reflect improved documentation, which we believe to be similarly laudable. While missing information on indications has decreased dramatically through this process, it remains to be determined why the nearly 1 in 4 patients with no documented information about indication underwent the procedure. Furthermore, the "other" category was added to capture clinical indications but was not added until 2011. The severity of each episode of diverticulitis was not characterized but surgeons were asked to include CT-confirmed episodes

and hospitalized events. Lastly, although SCOAP added these indication metrics with the expectation of a prospective evaluation contemporaneous to a planned intervention, the statewide intervention around indications developed organically and was likely different at each site and difficult to characterize completely. For example, dissemination of SCOAP indication metrics passed through a 'surgeon champion' at individual sites, and the messaging received at the level individual surgeons may have varied and is difficult to quantify.

This study describes a statewide performance surveillance and benchmarking network that used feedback and education about adherence to ASCRS recommended indications for elective colon surgery and trends in the indications across 49 hospitals. Concurrent to this initiative we found an increase in the proportion of cases that met expert-established guidelines for appropriate surgery, but nearly 1 in 3 still do not meet established criteria. Future work aims to better understand the reasons why patients undergo colectomy and incorporate patient-centered metrics. Including the full spectrum of relevant indications into a definition of appropriate care should advance the goal of providing more value-added surgical care.

TABLES AND FIGURES

Table 2.1. Patient characteristics, elective colon resection for diverticulitis

	Total cohort		<50 years old		50+ years old		
	N	%	N	%	N	%	p-value
	2724	100	655	24.1	2,069	75.9	
Mean age (median)	58.7 (59)		41.7 (43)		64.1 (63)		p < 0.001
Sex M	1266	46.5	409	62.4	857	41.6	p < 0.001
F	1458	53.5	246	37.6	1212	58.6	
Comorbidities							p < 0.001
0	1983	72.8	528	80.6	1455	70.3	
1	587	21.6	108	16.5	479	23.2	
2	123	4.5	13	2	110	5.3	
3	31	1.1	6	0.9	25	1.21	
Indications*							
Chronic complication	576	29.5	83	17.3	493	33.4	p < 0.001
Number of episodes							
1	311	15.9	93	19.4	218	14.7	p < 0.001**
2	257	13.1	71	14.8	186	12.6	
3 to 10	816	41.7	222	46.3	594	40.2	p=0.35***
> 10	59	3	17	3.5	42	2.8	
zero/unspecified	515	26.3	77	16	438	29.6	
Missing indication	766	28.1	175	26.7	591	28.6	p=0.360
Laparoscopic	1620	59.5	423	64.6	1197	57.9	p=0.002

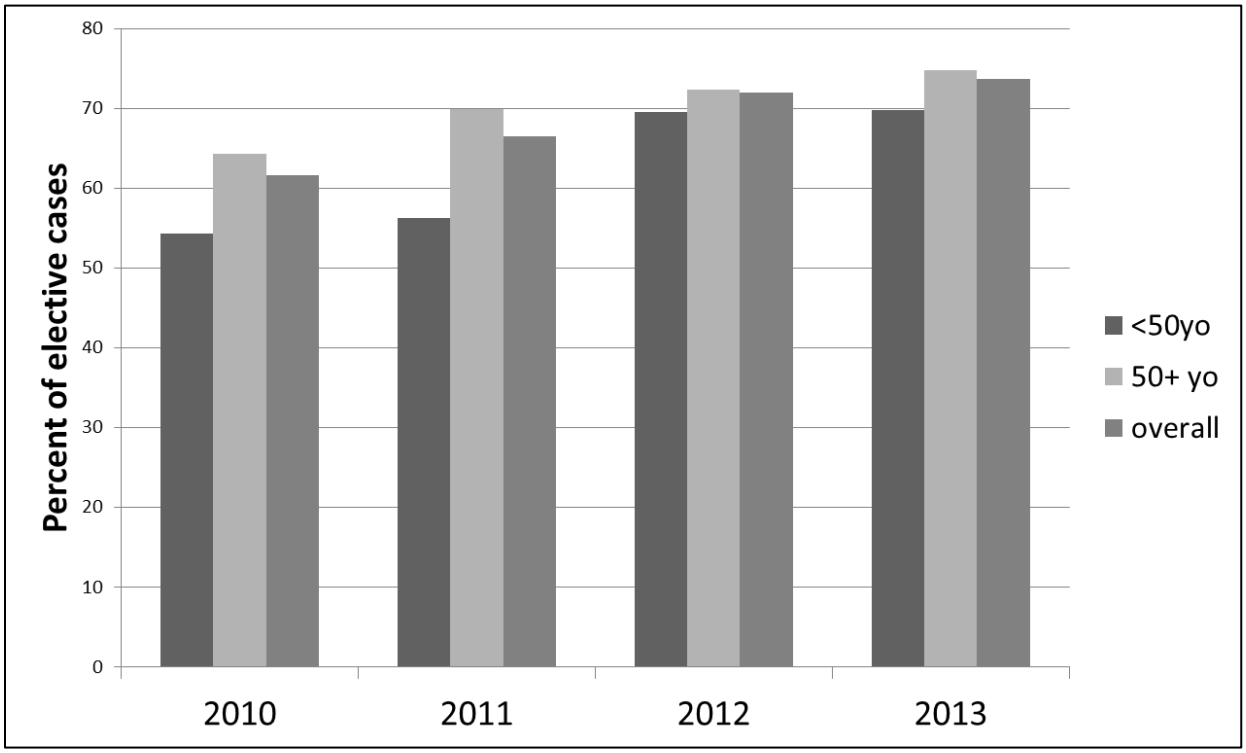
** Indication % calculated from population with complete information (total n = 1958, <50 n =480, 50+ n=1478)*
*** calculated as Pearson χ2 for all episode categories between younger (<50yo) and older (50+) patients*
**** calculated as Pearson χ2 for those with 3+ episodes between younger (<50yo) and older (50+) patients*

Table 2.2. Temporal trends in indications and approach

	2010		2011		2012		2013		
	N	%	N	%	N	%	N	%	**p-value**
Number of Episodes*									
1	76	18.1	83	18	65	13.4	87	16.6	p=0.28***
2	66	15.7	69	15	56	11.5	66	12.6	
3 to 10	144	34.2	177	38.5	237	48.8	258	49.2	p<0.001****
>10	10	2.4	11	2.4	20	4.1	18	3.4	
zero/unspecified	125	29.7	120	26.1	108	22.2	95	18.1	
Chronic complication*	122	27.9	158	37.9	126	25.4	170	31.5	p=0.69
Missing indication**	270	38.1	166	25.7	181	26.9	149	21.6	p<0.001
Laparoscopic	392	55.4	359	55.5	432	63.9	436	63.1	p<0.001

** calculated as proportion of all those with complete indication information*
*** calculated as proportion of all elective cases performed that year*
**** calculated as trend for all episode categories*
***** calculated as trend for 3+ episodes*

Figure 2.1. Proportion meeting ≥3 episode or chronic clinical indication



In patients younger than 50 years, the proportion of elective resections meeting chronic complication- or 3+ episode-based indications increased from 54.3 to 69.8%, (p=0.001) while in those who were 50 or older this proportion increased from 64.3% to 74.8% (p=0.003)

STUDY 3: ***The Impact of Delaying Elective Resection of Diverticulitis on Laparoscopic Conversion Rate*** [16]

ABSTRACT

Objective: To describe the factors associated with conversion and the impact of delayed elective colectomy on conversion from laparoscopy.

Background: Guideline-concordant delay in elective laparoscopic colectomy for diverticulitis may result in repeated bouts of inflammation. We aimed to determine whether conversion rates from elective laparoscopic colectomy are higher after multiple episodes of diverticulitis.

Methods: Prospective cohort study evaluating laparoscopic colectomy conversion rates for diverticulitis from 42 hospitals.

Results: Between 2010 and 2013, 1,790 laparoscopic colectomies for diverticulitis (mean age 57.8 ± 13; 47% male) resulted in 295 (16.5%) conversions. Conversion occurred more frequently in non-elective operations ($p<0.001$) and with fistula indications ($p=0.012$). Conversion rates decreased with surgeon case-volume ($p=0.028$). Elective colectomy exclusively for episode-based indications (n=784) had a conversion rate of 12.9%. Increasing episodes of diverticulitis were not associated with higher conversion rates, even among surgeons with similar experience levels.

Conclusion: Conversion from laparoscopic colectomy for diverticulitis did not increase after multiple episodes of diverticulitis. Delaying elective resection appears to not prevent patients from the benefits of laparoscopy.

INTRODUCTION

Acute diverticulitis is one of the most common indications for hospitalization related to the gastrointestinal (GI) tract in the United States (US), where it is estimated it will result in an estimated 300,000 admissions, 1.5 million days/year of inpatient care, and upwards of $1.8 billion in healthcare costs in 2014. [1,3] While diverticulitis is one of the leading indications for emergency colectomy and colostomy, [4,10] most colectomies for diverticulitis are performed electively to prevent recurrence or progression of disease.

Laparoscopic colectomy for the management of diverticular disease was more widely adopted after publication of initial studies in colorectal cancer in the early 2000s, [40,41] and contemporary evidence supports lower morbidity, shorter hospitalization, and higher patient satisfaction with the laparoscopic approach to diverticulitis.[4] Accordingly, most modern professional guidelines, including the 2014 update from the American Society of Colon and Rectal Surgeons (ASCRS), [1] recommend a laparoscopic approach to colectomy for diverticulitis.

However, given an increasingly recognized disconnect between episodes of diverticulitis and disease progression and recurrence, [4] the timing of elective colectomy has become less clear. The classic surgical dogma of operating after 2 episodes, maintained as recently as the 2000 ASCRS guidelines, [7] or delay operating until 3 or more episodes of diverticulitis as per the 2006 guidelines, [6] have given way to recommendations to avoid episode-based surgery altogether and consider each patient's need for elective colectomy on a case-by-case basis. [1]

Whether this delay in operating until after multiple episodes of diverticulitis, potentially increasing inflammation and scarring, has impacted the ability to complete operations laparoscopically remains to be determined. More so than laparoscopy for malignancy, laparoscopy for diverticulitis entails technical challenges of inflammation and adhesions, and failed laparoscopy rates are as high as 20%. [68,69] Conversion to an open operation negates the benefits of a laparoscopic approach, and there is growing interest in factors associated with failed laparoscopy for diverticulitis. In Washington State, where nearly

half of all colon operations are performed laparoscopically, [15] we sought to describe the factors associated with conversion and the impact of delayed elective colectomy on conversion from laparoscopy.

METHODS

This study was exempted from human subjects review by the University of Washington Human Subject Review Committee. The Comparative Effectiveness Research Translation Network (CERTAIN) provided research and analytic support to the Surgical Care and Outcomes Assessment Program (SCOAP). [54]

Data Sources and Definitions

The primary cohort was defined by consecutive patients who underwent laparoscopic colon resection for diverticulitis between January 1, 2010 to December 31, 2013 in 42 Washington State hospitals that participate in SCOAP. Sociodemographic, clinical, and operative details were extracted from inpatient medical records by trained chart abstractors at each clinical site. SCOAP metrics and data dictionary are available via a secure page at www.SCOAP.org. A modified Charlson comorbidity index for each patient was calculated. [21]

The SCOAP data collection platform for diverticulitis has been previously described, [15] and includes indications for the operation such as number of prior episodes of diverticulitis, chronic complications including gastrointestinal bleeding (GIB), stricture, and fistula, and an 'other' category to capture additional indications. Surgical approach was derived from the operative report and operating room logs looking for specific identification of open, laparoscopic, laparoscopic/hand-assisted, and laparoscopic/robotic-assisted surgical approaches. As in our prior definitions, the latter three categories were considered laparoscopic procedures on an intention to treat basis. [42] Conversion was defined through operative reports indicating that opening the abdomen was necessary to complete the procedure. Operations included were right/transverse hemicolectomy, left hemicolectomy, low anterior resection (including sigmoidectomy), and total abdominal colectomy. Because of a recognized association between laparoscopic procedural volume and conversion rates, [70] we describe the relationship between conversion

rates with surgical volume. Overall rates of procedures and conversions at the surgeon level were acquired using a de-identified code unique to each surgeon in the database (n=198 surgeons).

The main outcome of interest for this study was rate of conversion from laparoscopy. In addition, we describe rates of in-hospital complications and composite of adverse events (CAE). In-hospital complications include SCOAP's standard measures of cardiac, pulmonary, renal, infectious, or other complications requiring non-operative intervention. CAE included any of these with the addition of re-operative interventions and in-hospital deaths. [42] Conversion

The quality of indications data improved dramatically at SCOAP hospitals contemporaneous to a statewide benchmarking and educational initiative. [15] In order to minimize bias from chronic complication indications and missing data, we defined a subgroup *a priori* to include only those patients who underwent elective laparoscopic colectomy for an episode-based indication and had non-missing data.

Statistical Analysis

Patient characteristics, operative indications, and outcomes were summarized using frequency distributions for categorical variables, and mean (standard deviation) for continuous variables. We stratified our description by conversion from laparoscopy. Categorical variables were compared using Pearson $\chi 2$ statistic. Continuous variables were compared using the Student's t-test. Linear and logistic regression models were used to evaluate the association of case volume (clustered at surgeon level) and prior episode number, respectively, on conversion from laparoscopy, 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. A *p* value of less than 0.05 was considered statistically significant. All analysis was performed using STATA version 13 (STATA Corp, College Station, Tex).

RESULTS

Between 2010 and 2013, 49.5% (n=1,790) of all colectomies performed for diverticulitis in at Washington State's SCOAP hospitals were initiated laparoscopically and 16.5% (n=295) were converted. Patients undergoing colectomy had a mean age of 57.8 ±13 years and 47% were male. The demographics, indications and short-term outcomes for this cohort are summarized in **Table 3.1**. Notably, conversions occurred more frequently in patients who had non-elective procedures, chronic complication indications for their operation, or had right/transverse hemicolectomy performed. Patients who had conversions had a longer length of stay, operative time, increased discharges to skilled nursing facilities, and more in-hospital complications and CAEs (all statistically significant at $p<0.05$).

The surgeon-specific proportion of cases converted declined sharply with increasing case volume of laparoscopic colectomy (p= 0.03) (**Figure 3.1**). Operations performed for criteria concordant to the 2006 ASCRS guidelines (3+ episodes or chronic complication) did not correlate with surgical volume (p=0.31).

After adjusting for surgical volume, chronic complication indication, elective procedure, prior operation, BMI 30+, anatomic segment removed and year of operation, increasing episode number was not associated with higher likelihood of conversion (p= 0.189) (**Table 3.2**).

A subgroup of 784 patients underwent elective resection solely for episode-based indications (**Table 3.3**). These patients were younger (mean age of 55.3 ±11 years) and had fewer comorbidities than the remainder of the cohort. The conversion rate in this group was 12.9%. After adjustment for surgical volume, prior operation, BMI 30+, anatomic segment removed and year of operation, increasing episode number was not associated with higher likelihood of conversion in this subgroup (p=0.75).

DISCUSSION

To our knowledge, this study represents the largest cohort of laparoscopic colectomy for diverticulitis in which conversion rates were evaluated. Between 2010 and 2013 at SCOAP hospitals in Washington State, nearly 1,800 colectomies for diverticulitis were started laparoscopically, and 16.5% were

converted. In the subgroup of patients undergoing elective colectomy for an episode-based indication, the rate of conversion was 12.9%. Conversion was higher in non-elective cases and those with complicated disease indications, and was inversely related to surgical volume. After adjustment for several factors known to be predictive of conversion including surgeon experience, [71,72] increasing episodes of diverticulitis preceding surgery were not associated with increased conversion rate.

Laparoscopic colectomy was widely and rapidly adopted following publication of the safety and benefits of the procedure in colorectal cancer, [40,41] and its application to diverticulitis has shown benefits in morbidity, hospitalization, cosmesis and overall patient satisfaction, as substantiated by several randomized control trials and a systematic review. [4,73,74] However, laparoscopic colectomy for diverticulitis has unique technical difficulties that must be overcome to safely complete the operation, such as inflammation distorting landmark anatomy or fistulas to adjacent organs. While conversion rates for all indications for colorectal surgery are approximately 13% according to a large meta-analysis, [75] conversion rates specific for diverticulitis (which range between 2 and 20%) [9,10] have been more difficult to define, in part due to challenges in the management of elective versus non-elective cases, as well as differences between uncomplicated and complicated diverticulitis. In addition, existing literature suggests that surgeon experience, BMI, prior surgery, and presence of complicated disease contribute to conversion from laparoscopy. [71,72]

Our findings support the higher frequency of conversion in patients requiring urgent operation and those having complicated disease, specifically fistula. [71,72] Additionally, our study demonstrates that higher case volume is associated with lower conversion rate, as conversion rates dropped as surgeons approached 30 cases. This number should be interpreted cautiously, as the case volume is limited to years in study and only to diverticulitis indications. Published literature estimates the learning curve for all laparoscopic colectomies to be between 30 and 50 cases [70] and may be as high as 60 for diverticulitis. [76] Much of what is known about learning curves for laparoscopy comes from single centers of excellence, [70,76] while our cohort, including 198 surgeons across 42 hospitals, may be describing practice that is more generalizable to the wider surgical community. Conversion forfeits the benefits of laparoscopy, [71,77] and

our data confirm that converted cases had a longer operative time, hospitalization, and increased complications.

Overall, complicated diverticular disease is associated with a higher conversion rate than uncomplicated disease. This is not surprising as the most frequently described reasons for conversion are inflammation and adhesions, which occur more frequently when treating complicated diverticulitis. However, a higher rate of conversion with increasing prior episodes of diverticulitis, as would be suspected if multiple episodes were causing chronic inflammation, is not supported by our data. This finding is in line with other population-level studies suggesting that prior episodes are poor predictors of recurrence and progression of disease. [1,4]

Our study has certain limitations. First, the SCOAP registry is procedural rather than disease-based, and subject to confounding bias. For example, it may be that surgeons with higher surgical volume (and lower conversion rates) may be more likely to delay surgery until multiple episodes of diverticulitis. We did not, however, find an association between number of operations performed and proportion of cases concordant with 2006 ASCRS indications. In addition, the SCOAP data collection platform is based on operative reports, and there is heterogeneity in the technical aspects of how laparoscopic colectomy is performed and/or how individual surgeons describe these conversions (like hand-assistance, for example). Third, a substantial portion of patients was missing indications data. We have previously described the marked improvement in data quality in this cohort, [15] and note that we did not identify systematic differences in patients with and without indication data. Cognizant of this limitation in the data, we defined a subgroup with complete data for analysis, whose results parallel the patterns we saw in the larger cohort. Finally, we acknowledge that even this large cohort may be underpowered to make definitive claims about rates of conversion. As an estimate, to detect a difference between 20% and 10% conversion rates (alpha = 0.05, power =0.90) with various numbers of preceding episodes would require over 550 patients in each episode group.

Despite these limitations, the results from this statewide cohort of laparoscopic colectomy for diverticulitis add contemporary evidence to inform the management of a disease whose surgical

indications are in evolution. Our study also demonstrates that conversion rates from laparoscopy did not increase after multiple episodes of diverticulitis, while confirming previously published associations of conversion from laparoscopy to complicated disease and surgeon experience. These data suggest that delaying elective resection does not prevent patients from benefiting from the advantages of laparoscopic surgery.

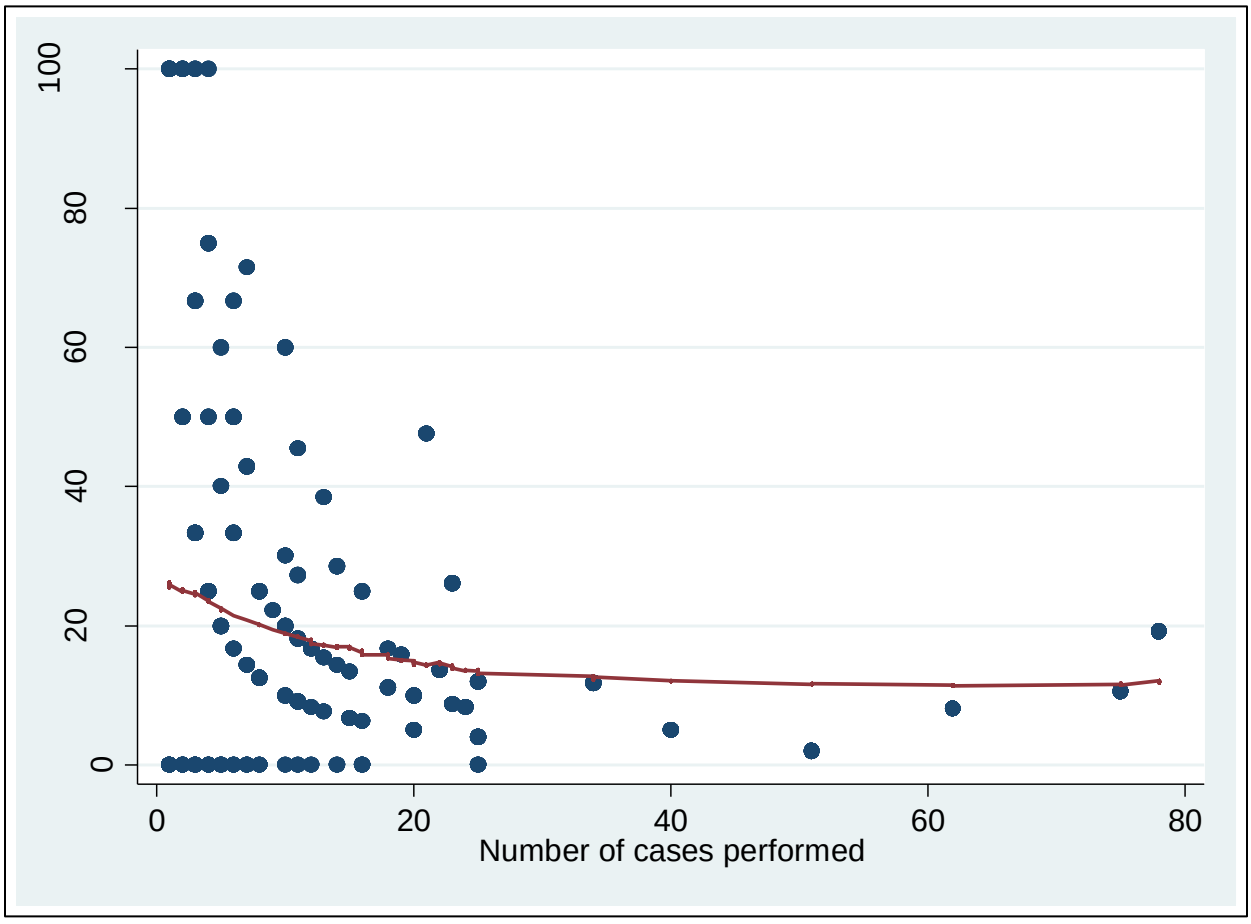
TABLES AND FIGURES

Table 3.1. Demographics, indications and outcomes, stratified by conversion.

		Not converted		Converted		Total cohort		
		N	%	N	%	N	%	
		1495	83.5	295	16.5	1790	100	p-value
Mean age (SD)		57.5 (12.6)		59.1 (12.9)		57.8 (12.7)		0.054
Sex	M	707	47.3	135	45.8	842	47.0	0.63
	F	788	52.7	160	54.2	948	53.0	
White		1,307	87.4	254	86.1	1,561	87.2	0.52
Comorbidities								0.29
	0	1,108	74.1	214	72.5	1,322	73.9	
	1	311	20.8	59	20.0	370	20.7	
	2	59	4.0	15	5.1	74	4.1	
	3	17	1.1	7	2.4	24	1.3	
BMI 30+		620	41.5	115	39.0	735	41.1	0.43
Indications								
Non-elective		114	7.6	56	19.0	170	9.5	p<0.001
Number of prior episodes*								p<0.001
	None	115	12.1	43	23.4	158	13.9	
	1	142	14.9	31	16.9	173	15.2	
	2	137	14.4	27	14.7	164	14.5	
	3 to 10	520	54.7	73	39.7	593	52.5	
	> 10	37	4.0	10	5.4	47	4.0	
Chronic complication**		238	16.1	65	22.1	303	17.1	0.012
	Colovesicular fistula	120	8.1	34	11.6	154	8.7	0.054
	Current GI bleed	33	2.2	7	2.4	40	2.3	0.87
	Stricture	61	4.1	17	5.8	78	4.4	0.20
	Other fistula	36	3.1	15	7.1	51	3.8	0.01
Missing indication		453	30.3	81	27.5	534	29.8	0.33
Operation type								
	Right Hemicolectomy	72	4.8	26	8.8	98	5.5	0.01
	Left Hemicolectomy	450	30.1	83	28.1	533	29.8	0.50
	Low Anterior Resection***	973	65.1	203	68.8	1,176	65.7	0.22
	Total Abdominal Colectomy	15	1	1	0.3	16	0.9	0.27
Prior surgery		509	34.1	117	40.0	626	35.0	0.17
Outcomes								
Mean OR time, min (SD)		174 (74)		197 (92)		178 (78)		p<0.001
Mean Length of Stay (SD)		5.2 (7.0)		7.2 (5.4)		5.6 (6.8)		p<0.001
Discharge home		1,430	95.7	266	90.2	1,696	94.8	0.002
In-hospital complication		90	6.0	49	16.6	139	7.8	p<0.001
CAE****		140	9.4	70	23.7	210	11.7	p<0.001

** Number of episode % calculated from population with known episode information (total n = 1135, non-converted n =951, converted n=184)*
*** calculated as Pearson χ2 for any chronic complication indication between converted and non-converted cases*
**** Low Anterior Resection category includes sigmoidectomy*
*****Composite Adverse Events (CAE), includes complications as well as re-operative interventions and in-hospital deaths*

Figure 3.1. Surgeon-level relationship between number of operations and rate of conversion.



The surgeon-specific proportion of cases converted declined with increasing case volume of laparoscopic colectomy (p= 0.03).

Table 3.2. Association between number of prior episodes and likelihood of conversion.

	Unadjusted Association				Adjusted Association*			
Conversion	OR	CI		P	OR	CI		p
Prior episodes**								
None	REF	REF			REF	REF		
1	0.58	0.35	0.99	0.04	0.71	0.41	1.22	0.22
2	0.53	0.31	0.91	0.02	0.59	0.33	1.05	0.07
3 to 10	0.38	0.24	0.58	p<0.001	0.53	0.33	0.85	0.01
10+	0.72	0.33	1.58	0.42	0.99	0.44	2.25	0.99
Surgical volume	0.99	0.98	0.99	p<0.001	0.99	0.98	0.99	p<0.001
Chronic complication	1.48	1.09	2.02	0.01	1.37	0.96	1.95	0.08
Elective	0.35	0.25	0.50	p<0.001	0.43	0.29	0.65	p<0.001
BMI 30+	0.90	0.70	1.16	0.43	0.92	0.69	1.21	0.54
Prior operation	0.79	0.61	1.02	0.07	0.75	0.57	1.00	0.052
Right Hemicolectomy	1.91	1.20	3.05	0.01	1.63	0.93	2.83	0.086
Year	0.86	0.77	0.96	0.01	0.87	0.77	0.98	0.03

** Adjusted for all other variables listed*

***Association listed for each category of prior episodes using no prior episodes as reference; overall associations for increasing category of episode are OR 0.91 (0.83, 0.99; p=0.026) and OR 0.94 (0.87, 1.03; p=0.189) for unadjusted and adjusted models, respectively.*

Table 3.3. Elective surgery solely for episode-based indication: subgroup demographics and indications stratified by conversion.

		Not converted		Converted		
		N	%	N	%	
		683	87.12	101	12.88	p value
Mean age (SD)		55.0	(11.6)	56.9	(12.7)	0.13
Sex	M	311	45.53	55	54.46	0.09
	F	372	54.47	46	45.54	
White		605	88.58	88	87.13	0.44
Comorbidities						0.53
	0	513	75.11	70	69.31	
	1	146	21.38	25	24.75	
	2	20	2.93	5	4.95	
	3	4	0.59	1	0.99	
BMI 30+		289	42.31	47	46.53	0.42
Indications						
Number of prior episodes						0.19
	1	91	13.32	17	16.83	
	2	102	14.93	14	13.86	
	3 to 10	459	67.2	61	60.4	
	> 10	31	4.54	9	8.91	
Operation type						
	Right Hemicolectomy	21	3.07	5	4.95	0.33
	Left Hemicolectomy	226	33.09	26	25.74	0.14
	Low Anterior Resection*	447	65.45	74	73.27	0.12
	Total Abdominal Colectomy	5	0.73	0	0	0.39
Prior abdominal surgery		231	33.82	42	41.58	0.13

** Low Anterior Resection category includes sigmoidectomy*

SUMMARY AND FUTURE DIRECTIONS

The three studies presented in this thesis suggest a disconnect between the use of elective colectomy for prevention of emergency surgery at a population level. Furthermore, this data supports the growing belief that diverticulitis recurrences, as defined by episodes of diverticulitis, are a poor predictor for future emergencies or complications, and should not guide threshold to operate or operative approach.

Still important gaps in understanding of when elective surgery is appropriate remain. First, severity of diverticulitis and complicated diverticulitis are problematic to measure with administrative databases, as diagnostic and billing codes for abscess, peritonitis and perforation are often secondary and inconsistently recorded. Increasing outpatient management suggests those requiring inpatient hospitalizations today are "sicker" than they were in the past [1,4,34]. However, studies looking at complicated diverticular disease in hospitalized populations have found relative stability of patients with "complicated" diverticulitis [5,15,20].

Furthermore, increasingly guidelines have recommended individualizing the decision for elective colectomy [1,12,13]. However, it remains to be determined which discrete measures of patient experience should be used to assess whether a resection is appropriate. Surgeons often report that their patients may not meet the professional recommendations but have reasonable indications for elective colectomy such as anxiety related to the possibility of an emergency, fear of travel, uncertainty about insurance and childcare coverage, intolerance of oral antibiotics or lingering symptoms and impaired quality of life (QOL). These are factors that may also be particularly relevant among younger patients (<50 years old). Attempts to quantify the drivers of impaired QOL have been limited to small cohorts and suffer from response rates as low as 50% [4,78]. Accounting for these symptoms is problematic without the use of standard evaluations that have not been a part of most prior studies.

To address these and other evidence gaps, my future work will aim to accomplish the following three aims. The first aim will be to determine the contemporary, nationwide patterns of practice after recovery from an episode of diverticulitis. Most prior studies on practice patterns [10,11,17] have focused on in-hospital care using administrative data, missing outpatient management (e.g., oral antibiotics) that has

become increasingly common. Because of this limitation, we do not actually know if recommendations about delaying surgery are being followed. Therefore, it remains to be determined if growth in the use of elective surgery is guideline-concordant or in which groups earlier resection is more common. To address these gaps, I propose to use the MarketScan® Databases including nationwide, inpatient/outpatient claims, and antibiotic prescriptions specific to the treatment of a diverticulitis event. I hypothesize that patients commonly undergo elective resection after ≤ 2 episodes, and this is more common in those having a laparoscopic procedure or younger than 50 years.

Second, there is a need to assess patient and provider factors associated with decision making related to elective colon resection among patients evaluated by a surgeon. There are indications beyond the number of diverticulitis episodes that may drive the recommendation and use of elective resection including residual pain, gastrointestinal and systemic symptoms, and intolerance of oral antibiotics. How often these symptoms and non-clinical factors are the indication for surgery has not been assessed. To address this gap, we will expand an existing registry of patients with diverticulitis evaluated by surgeons across Washington State to assess clinician- and patient-reported indications. I hypothesize that residual gastrointestinal and/or inflammatory symptoms and non-clinical factors are common for patients with ≤ 2 episodes prior to surgery, and that this occurs more often in younger patients.

Third, better data is needed to assess the burden of diverticulitis over time (e.g., gastrointestinal symptoms, antibiotic use, effect on work productivity, and QOL outcomes). The burden of diverticulitis on the lives of those who do and do not undergo elective resection and potential factors associated with greater impact (e.g., age < 50) have not been carefully assessed. As a result, clinicians can offer little guidance about the expected outcomes of surgical and non-surgical treatment. To address these gaps, a large, statewide cohort of those who have recovered from a confirmed episode of diverticulitis is needed, and can be recruited from hospital admission and emergency room visit records. Impact of diverticulitis using standardized instruments will be assessed in this cohort. I hypothesize there is significant patient-reported impact in the first year after an initial episode of diverticulitis, diminishing in subsequent years, and that younger patients report greater burden.

Addressing these evidence gaps using national and statewide data will inform decision making and be critical in the development of future comparative studies of strategies related to elective colon resection and other novel treatments for diverticulitis.

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APPENDICES

Appendix 1. ICD-9 Diagnostic codes used for Study 1.

ICD-9	Diverticulitis
562.11	Diverticulitis without hemorrhage
562.13	Diverticulitis with hemorrhage

ICD-9	Colectomy
17.3	Laparoscopic partial excision of large intestine
17.31	Laparoscopic multiple segmental resection of large intestine
17.32	Laparoscopic cecectomy
17.33	Laparoscopic right hemicolectomy
17.34	Laparoscopic resection of transverse colon
17.35	Laparoscopic left hemicolectomy
17.36	Laparoscopic sigmoidectomy
17.39	Other laparoscopic partial excision of large intestine
45.41	Excision of lesion or tissue of large intestine
45.7	Open and other partial excision of large intestine
45.71	Open and other multiple segmental resection of large intestine
45.72	Open and other cecectomy
45.73	Open and other right hemicolectomy
45.74	Open and other resection of transverse colon
45.75	Open and other left hemicolectomy
45.76	Open and other sigmoidectomy
45.79	Other and unspecified partial excision of large intestine
45.8	Total intra-abdominal colectomy
45.81	Laparoscopic total intra-abdominal colectomy
45.82	Open total intra-abdominal colectomy
45.83	Other and unspecified total intra-abdominal colectomy
45.92	Anastomosis of small intestine to rectal stump
45.93	Other small-to-large intestinal anastomosis
45.94	Large-to-large intestinal anastomosis
46.01	loop ileostomy
46.03	Exteriorization of large intestine
46.04	Resection of exteriorized segment of large intestine
46.1	Colostomy
46.10	Colostomy, not otherwise specified
46.11	Temporary colostomy
46.13	Permanent colostomy
46.14	Delayed opening of colostomy
462	Ileostomy
4620	Ileostomy, not otherwise specified
4621	Temporary ileostomy
4622	Continent ileostomy
4623	Other permanent ileostomy
4624	Delayed opening of ileostomy
46.43	Other revision of stoma of large intestine
48.62	Anterior resection of rectum with synchronous colostomy
48.63	Other anterior resection of rectum

ICD-9	Percutaneous drain:
54.91	percutaneous abdominal drainage

ICD-9 Laparoscopic Colectomy:

17.3 Laparoscopic partial excision of large intestine
17.31 Laparoscopic multiple segmental resection of large intestine
17.32 Laparoscopic cecectomy
17.33 Laparoscopic right hemicolectomy
17.34 Laparoscopic resection of transverse colon
17.35 Laparoscopic left hemicolectomy
17.36 Laparoscopic sigmoidectomy
17.39 Other laparoscopic partial excision of large intestine
45.81 Laparoscopic total intra-abdominal colectomy

Or any ICD-9 colectomy code PLUS

54.21 Laparoscopy
54.51 Laparoscopic lysis of peritoneal adhesions

Appendix 2. SCOAP Diverticulitis operative report guide