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SSAT PLENARY PRESENTATION

Declining Rates of Surgery for Inflammatory Bowel Disease in the Era of Biologic Therapy

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Abstract

Background Medical therapy for inflammatory bowel disease (IBD) has markedly advanced since the introduction of biologic therapeutics, although surgery remains an important therapeutic strategy for both Crohn's disease (CD) and ulcerative colitis (UC). This study evaluated how rates of bowel resection surgery and post-operative mortality for IBD have changed over the last decade in the era of biologic therapies.

Methods The Nationwide Readmission Database (NRD) was queried for patients with IBD (based on ICD-9 and -10 diagnosis and procedure codes) who were hospitalized between 2010 and 2017. Longitudinal trends in bowel resection surgery, urgent surgery, and post-operative mortality were analyzed.

Results During the 8-year period, a total of 1795,266 IBD-related hospitalizations (1,072,110 with CD and 723,156 with UC) were evaluated. There was an increase in the annual number of IBD patients hospitalized, but a statistically significant decrease in the proportion of IBD patients undergoing surgery, from 10 to 8.8% ($p < 0.001$) for CD and 7.7 to 7.5% ($p < 0.001$) for UC. From 2014 through 2017, the proportion of urgent surgeries remained stable around 25% ($p = 0.16$) for CD and decreased from 21 to 14% ($p < 0.001$) for UC. For CD, the rate of post-operative 30-day mortality varied between 1.2 and 1.6% and for UC decreased from 5.8 to 2.3% ($p < 0.001$).

Conclusions Analysis of a nationwide dataset from 2010 to 2017 determined that despite an increase in total admissions for IBD, a smaller proportion of hospitalized patients underwent surgery. A greater proportion of surgeries for UC were performed on an elective basis, and overall the rates of post-operative mortality for CD and UC decreased. The growth of biologic medical therapy during the study period highlights a probable contributing factor for the observed changes.

Keywords Inflammatory bowel disease · Crohn's disease · Ulcerative colitis · Surgery · Post-operative mortality · Urgent · Biologic era

Introduction

The last decade has witnessed increased utilization of biologic therapies for inflammatory bowel disease (IBD) [1–3]. Although surgery remains an essential treatment option for inflammatory bowel disease, successful implementation of effective and timely biologic therapies may reduce the need for surgery.

Twenty percent of ulcerative colitis and 80% of Crohn's disease (CD) patients will undergo surgery during their lifetime [4]. A total proctocolectomy for ulcerative colitis (UC) is an option for patients with disease refractory to medical treatment, and can be curative and improve the quality of life for UC patients [5]. In addition for medically refractory Crohn's disease (CD), surgery is

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also commonly employed for complications such as strictures, fistulas, and abscesses[6].

With the advent of biologic therapy starting with the FDA approval of infliximab in 1998 and more aggressive treatment goals of achieving mucosal healing[7], one would predict a decrease in the proportion of IBD patients requiring surgery. Yet, studies to date have lacked consensus. A study of the National Inpatient Sample (NIS) showed that surgery rates for CD and UC were unchanged from 2003 to 2012[8], while a Spanish study showed a decrease in the rate of surgery for CD following anti-TNF approval but no change for UC[9], and a Danish study showed a decrease in the rate of surgery for both CD and UC[10]. This study aimed to further investigate this trend, using a large US admissions database.

Furthermore, if the rate of IBD surgery is decreasing due to biologic therapy, the hypothesis is that those requiring surgery are presenting more urgently with more severe disease, and thus have higher post-operative mortality. Post-operative mortality in the era of biologic therapy has been studied in smaller cohorts. A study of a New York State database showed an increase in mortality after nonelective surgery in UC but a decrease in CD[11]. A Canadian study with a post-colectomy mortality rate of 1.5% in UC, identified older age, emergent surgery, and more than 2 comorbidities as independent predictors of post-operative complications[12]. However, few studies have been published on the subject using US nationwide databases.

This study sought to utilize a US nationwide database to evaluate whether rates of IBD-related surgery, urgent surgery, and post-operative mortality in Crohn's disease (CD) and ulcerative colitis (UC) have changed over the last decade in the era of biologic therapies.

Materials and Methods

The Nationwide Readmission Database (NRD) was developed by the Healthcare Cost and Utilization Project (HCUP) and provides nationally representative estimates of approximately 36 million all-payer acute care hospitalizations each year throughout the USA[13]. The NRD captures and links all admissions for a patient in a given calendar year within a given state, which allows for evaluation of each patient's history of hospitalizations throughout the year. It does not capture prior hospitalizations beyond the calendar year. The NRD also includes data on demographics, diagnoses, procedures, payer mix, death, and hospital characteristics.

The NRD from all available years (2010 through 2017) was queried for patients with CD and UC using the International Classification of Diseases, Clinical Modification, Ninth and Tenth Revision (ICD-9-CM, ICD-10-CM) codes in all diagnosis positions (Supplemental Table 1). Patients with concurrent diagnoses of CD and UC were excluded. IBD-related surgeries were defined as having undergone a small bowel resection (including ileocolic resection) or colectomy (segmental colectomy, proctectomy, total colectomy with ileostomy, or total proctocolectomy) (Supplemental Table 2). The index hospitalization was defined as the first hospitalization or first hospitalization involving an IBD-related surgery (if performed) for each patient in the calendar year.

The following variables were obtained from the NRD: patient age, sex, medical comorbidities, median household income for patient's zip code, primary payor, elective vs. non-elective admission, hospitalization day number for IBD-related surgery, and death. The medical comorbidities used to calculate the Charlson-Deyo Comorbidity Index included myocardial infarction, congestive heart failure, cerebrovascular accident, peripheral vascular disease, chronic obstructive pulmonary disease, diabetes, chronic kidney disease, dementia, peptic ulcer disease, hepatic disease, rheumatologic disease, human immunodeficiency virus infection, and cancer[14]. Protein calorie malnutrition was included as an additional variable and identified based on ICD-9/-10 codes. Hospital characteristics included bed size (small, medium, large), hospital control/ownership (public, not-for-profit private, investor-owned private), and teaching status (metropolitan non-teaching, metropolitan teaching, rural). The database did not include information on race, medications, endoscopy reports, histopathology, results of radiographic studies, or any IBD-specific lab results such as C-reactive protein or fecal calprotectin.

The primary outcome was all IBD-related surgery. Secondary outcomes included urgent surgery (defined as surgery within 2 days of a non-elective admission) and post-operative 30-day mortality. All of the variables listed above were included in the univariable and multivariable analyses for post-operative 30-day mortality.

Results

There were 1,072,110 patients hospitalized with CD and 723,156 with UC between 2010 and 2017. Patients who underwent surgery were younger with fewer comorbidities, more often malnourished, from higher income households, and more likely to have private insurance than those who did not have surgery (Table 1). Compared to the non-surgical group, the proportion of men was greater in the surgical group for both CD and UC. Among the patients who had surgery a higher proportion were at larger hospitals, hospitals with private nonprofit ownership, teaching hospitals, and in more populated areas than those who did not undergo surgery (Table 1). For both UC and CD, 59% of the patients who underwent surgery were admitted electively (Table 1). The annual number of patients hospitalized with CD increased from 126,337 to

Table 1 Demographics of patients included in analysis, stratified by surgery or no surgery

		Crohn's disease $N = 1,072,109$			Ulcerative colitis $N = 723,156$		
		No surgery $N = 982,074$	Surgery $N = 90,035$	p values	No surgery $N = 675,264$	Surgery $N = 47,892$	p values
Mean age		50.40 ± 0.10	44.57 ± 0.17	< 0.01	55.05 ± 0.10	52.50 ± 0.24	< 0.01
Gender	Male	405,471 (41%)	43,106 (48%)	< 0.01	300,887 (45%)	25,793 (54%)	< 0.01
	Female	576,603 (59%)	46,929 (52%)		374,337 (55%)	22,098 (46%)	
Charlson Comorbidity Index	0	556,617 (57%)	67,479 (75%)	< 0.01	349,675 (52%)	28,665 (60%)	< 0.01
	1–2	311,556 (32%)	18,268 (20%)		223,001 (33%)	13,795 (29%)	
	3+	113,901 (11%)	4289(5.0%)		102,589 (15%)	5432 (11%)	
Malnutrition		68,379 (7%)	12,673(14%)	< 0.01	52,604 (8%)	8928(19%)	< 0.01
Elective admission		158,078 (16%)	52,870 (59%)	< 0.01	111,501 (17%)	28,447 (59%)	< 0.01
ZIP income quartile[a]	Lowest	242,622 (25%)	19,133 (21%)	< 0.01	150,146 (22%)	9728 (20%)	< 0.01
	Second	247,873 (25%)	22,125 (25%)		161,489 (24%)	11,634 (24%)	
	Third	248,174 (25%)	23,913 (27%)		173,962 (26%)	12,760 (27%)	
	Highest	229,705 (24%)	23,687 (26%)		118,001 (27%)	13,036 (27%)	
Payor	Medicare	371,707 (38%)	19,607 (22%)	< 0.01	285,599 (42%)	16,288 (34%)	< 0.01
	Medicaid	134,828 (14%)	10,193 (11%)		73,057 (11%)	4274 (8.9%)	
	Private	389,459 (40%)	53,399 (59%)		264,679 (40%)	24,804 (52%)	
Hospital bed size	Small	138,470 (14%)	9267 (10%)	< 0.01	94,264 (14%)	5174 (11%)	< 0.01
	Medium	248,284 (25%)	19,200 (21%)		167,993 (25%)	9178 (19%)	
	Large	595,320 (61%)	61,569 (68%)		413,005 (61%)	33,539 (70%)	
Hospital ownership	Government	107,491 (11%)	9183 (10%)	< 0.01	70,344 (10%)	4639 (9.7%)	< 0.01
	Private not-profit	754,278 (77%)	73,879 (82%)		524,118 (78%)	39,519 (83%)	
	Private invest-own	120,305 (12%)	6973 (7.7%)		80,803 (12%)	3734 (7.8%)	
Hospital urban/rural designation	Large metro	555,153 (57%)	55,406 (62%)	< 0.01	406,931 (60%)	30,667 (64%)	< 0.01
	Small metro	337,020 (34%)	30,806 (34%)		216,036 (32%)	15,690 (33%)	
	Micropolitan	67,011 (6.8%)	3214 (3.6%)		39,960 (5.9%)	1327 (2.8%)	
	Non-urban	22,891 (2.3%)	610 (0.7%)		12,338 (1.8%)	208 (0.4%)	
Teaching status of hospital	Metro non-teach	303,997 (31%)	21,326 (25%)	< 0.01	205,868 (31%)	10,204 (21%)	< 0.01
	Metro teaching	588,176 (60%)	64,885 (72%)		416,999 (62%)	36,152 (76%)	
	Rural	89,902 (9.2%)	3824 (4.2%)		52,298 (7.7%)	1535(3.2%)	

[a] Median household income for patient's zip code

143,700 and from 82,713 to 97,597 in UC (Fig. 1). The absolute number of surgeries performed for CD remained stable from 12,708 in 2010 to 12,697 in 2017 and for UC increased from 6409 in 2010 to 7403 in 2017 (Fig. 2). Over the study period, the proportion of hospitalized CD patients undergoing surgery decreased from 10 to 8.8% ($p < 0.001$) and from 7.7 to 7.5% for UC patients ($p < 0.001$) (Fig. 3). The proportion of urgent surgeries

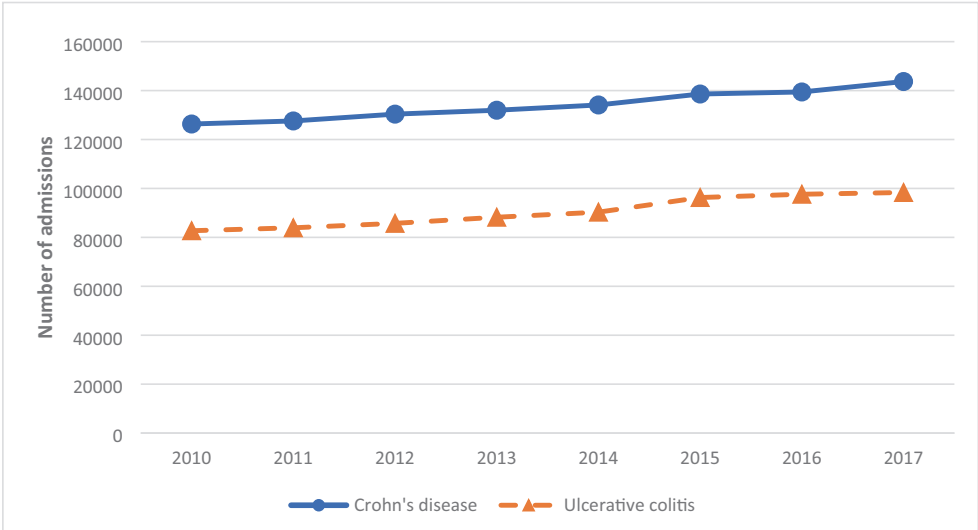

Fig. 1 Total number of patients with Crohn's disease and ulcerative colitis who are hospitalized each year. Multiple hospitalizations for the same patient within a given year are counted as one hospitalization

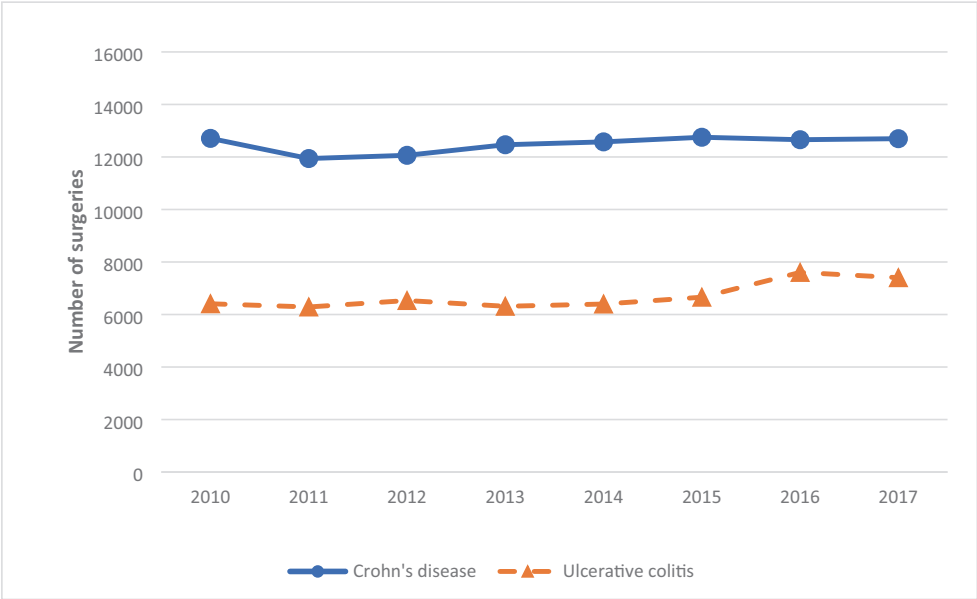

Fig. 2 Absolute number of surgeries per year for patients with Crohn's disease and ulcerative colitis

(surgery within 2 days of non-elective admission) stayed stable from 25% in 2014 to 24% in 2017 for CD ($p = 0.16$) and dropped from 21 to 14% for UC ($p < 0.001$) (Fig. 4). Patients who underwent urgent surgery for both UC and CD were older with more comorbidities, more likely to have Medicare or Medicaid, from lower income households, and more often malnourished than those who had elective surgery. Those who had urgent surgery for Crohn's were more likely to be male, and for UC were more likely to be female. Among those who had urgent surgery a higher proportion were at government or private investor owned hospitals, non-teaching hospitals, and in less populated areas than those who underwent elective surgery (Table 2). Post-operative 30-day mortality in urgent and elective cases fluctuated between 1.2 and 1.6% in CD and decreased from 5.8 to 2.3% in UC ($p < 0.001$) (Fig. 5).

Multivariable analysis showed older age, higher Charlson Comorbidity Index, lower income, and non-elective admission to be predictors of post-op mortality for UC and CD, while rural hospital was an additional predictor for post-op mortality in CD (Table 3).

When post-operative mortality was broken down by urgent or elective surgery, multivariable analysis showed that age and Charlson Comorbidity Index were risk factors for post-operative mortality for all surgeries, UC or CD and urgent or elective (Table 4). For elective UC surgery, income, malnutrition, and admission at a private non-profit hospital were also risk factors for post-operative mortality. For elective CD

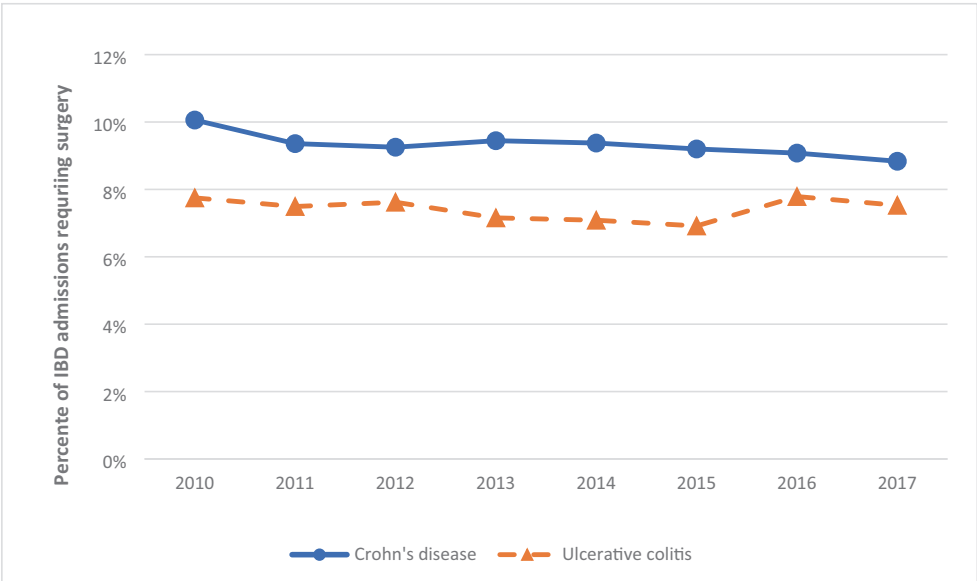

Fig. 3 Overall surgical rates for patients with Crohn's disease ($p < 0.001$) and ulcerative colitis ($p < 0.001$)

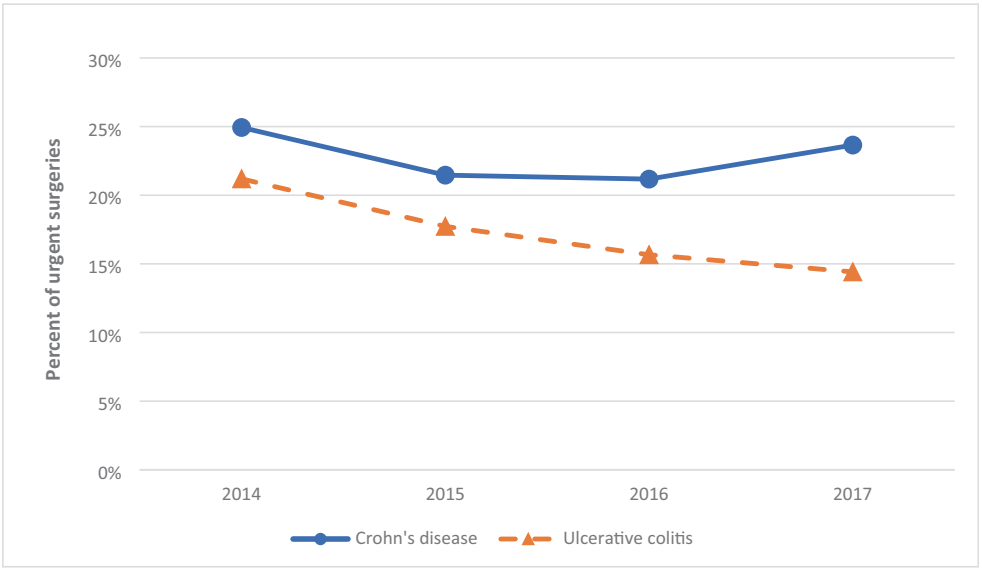

Fig. 4 Trends in rates of urgent surgery for Crohn's disease ($p = 0.16$) and ulcerative colitis ($p < 0.001$)

surgery, income and malnutrition were the only additional risk factors, and for urgent CD surgery, admission at a private non-profit or private investor–owned hospital, admission at a rural hospital, and malnutrition were also risk factors for 30-day post-operative mortality.

Discussion

Infliximab was approved to treat moderate to severe Crohn's disease in 1998 and ulcerative colitis in 2005. Between 1999 and 2012, 59,875 infusions of infliximab were administered in the Crohn's Therapy, Resource, Evaluation, and Assessment Tool (TREAT) Registry[15]. Examining Johnson and Johnson sales data, the sale of infliximab increased incrementally every year of the study from $3099 million in 2010 to $4525M in 2017[16]. A 2018 study of US insurance data showed an increase in biologic use in CD from 20 to 40% between 2009 and 2015 and 5 to 16% in UC patients[17]. This nationwide trend suggests that the use of these medications became more entrenched into the framework of IBD treatment for the general population, and not just specialized centers. The greater use of biologic therapy indicates that they provided an important alternative to surgery.

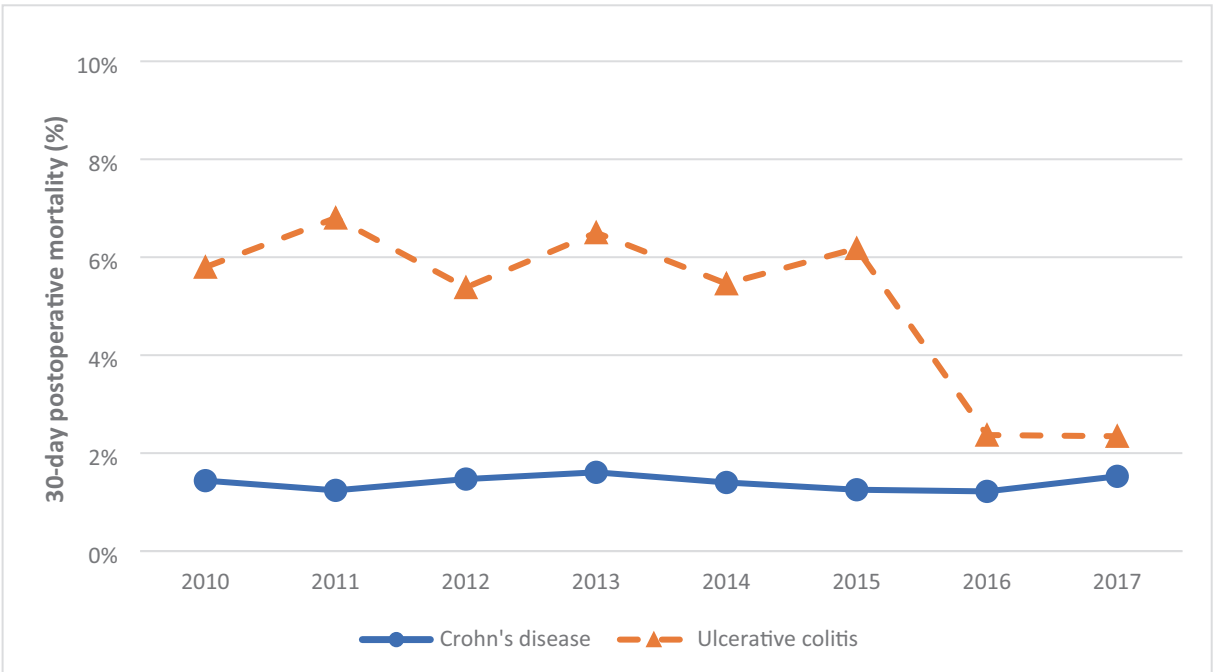

Fig. 5 Post-IBD surgical mortality within 30 days for Crohn's disease ($p < 0.01$) and ulcerative colitis ($p < 0.001$)

Table 2 Demographics of patients undergoing elective vs. urgent surgery

		Crohn's disease patients who had surgery $N = 90,035$			Ulcerative colitis patients who had surgery $N = 47,892$		
		Elective surgery $N = 60,383$	Urgent surgery $N = 29,653$	p values	Elective surgery $N = 33,096$	Urgent surgery $N = 14,796$	p values
Mean age		44.21 ± 0.18	45.29 ± 0.27	< 0.01	49.63 ± 0.25	58.91 ± 0.36	< 0.01
Gender	Male	28,139 (47%)	14,968 (50%)	< 0.01	18,396 (56%)	7397 (50%)	< 0.01
	Female	32,244 (53%)	14,685 (50%)		14,700 (44%)	7399 (50%)	
Charlson Comorbidity Index	0	46,282 (77%)	21,198 (71%)	< 0.01	21,443 (52%)	7222 (49%)	< 0.01
	1–2	11,555(19%)	6712 (23%)		8641 (33%)	5154 (35%)	
	3+	2546 (4.2%)	1743(5.8%)		3011 (15%)	2420 (14%)	
Malnutrition		6830 (11%)	5843(20%)	< 0.01	4317 (8%)	4611(10%)	< 0.01
ZIP income quartile*	Lowest	11,944 (20%)	7189 (25%)	< 0.01	6319 (19%)	3409 (23%)	< 0.01
	2nd	14,644(25%)	7480 (26%)		8012 (25%)	3622 (25%)	
	3rd	16,227 (27%)	7687 (26%)		8908 (27%)	3852 (27%)	
	Highest	16,798 (28%)	6889 (23%)		9384 (29%)	3652 (25%)	
Payor	Medicare	12,145 (20%)	7463 (25%)	< 0.01	8958 (27%)	7330 (50%)	< 0.01
	Medicaid	6246 (10%)	3947 (13%)		2806 (8.5%)	1468 (10%)	
	Private	38,613 (64%)	14,786 (50%)		19,711 (60%)	5093 (34%)	
Hospital bed size	Small	6346 (11%)	2921 (10%)	0.02	3690 (11%)	1485 (10%)	0.10
	Medium	12,274 (20%)	6926 (23%)		6069 (18%)	3109 (21%)	
	Large	41,763 (69%)	19,806 (67%)		23,337 (71%)	10,202 (69%)	
Hospital ownership	Government	5760 (10%)	3423 (12%)	< 0.01	3035 (9.2%)	1603 (11%)	< 0.01
	Private not-profit	51,003 (84%)	22,877 (77%)		28,122 (85%)	11,398 (77%)	
	Private invest-own	3620 (6.0%)	3353 (11%)		1939 (5.8%)	1795 (12%)	
Hospital urban/rural designation	Large metro	38,515 (64%)	16,891 (57%)	< 0.01	21,856 (66%)	8810 (60%)	< 0.01
	Small metro	19,999 (33%)	10,806 (36%)		10,506 (32%)	5185 (35%)	
	Micropolitan	1555 (2.6%)	1659 (5.6%)		639 (1.9%)	688 (4.6%)	
	Non-urban	314 (0.5%)	297 (1.0%)		95 (0.3%)	113 (0.8%)	
Teaching status of hospital	Metro non-teach	11,283 (19%)	10,044 (34%)	< 0.01	5333 (16%)	4871 (33%)	< 0.01
	Metro teaching	47,231 (78%)	17,654 (60%)		27,029 (82%)	9124 (62%)	
	Rural	1869 (3.0%)	1955 (6.6%)		734 (2.2%)	801(5.4%)	

*Median household income for patient's zip code

A study of the National Inpatient Sample (NIS) from 1998 to 2005 showed an increase in hospitalizations for both CD and UC with no change in the rates of surgical care[18]. Bewtra et al. showed that in the US, over the 14-year period from 1990 to 2003, there was no significant change in the annual rates of bowel resection surgeries for IBD[19]. A US nationwide study to evaluate surgical trends in the subsequent decade has not been performed.

Despite an increasing incidence of IBD[20] and increasing rates of hospitalizations[21], our study shows that during the past decade, surgery rates for IBD have declined. The results are similar to those of Ahmad et al. in the United Kingdom's Hospital Episode Statistics (HES) database, where a significant decrease in the total and urgent surgery rates for CD occurred between 2003 and 2004 and 2012 and 2013 and the Canadian study Ma et al. which showed a decrease in both total and urgent surgery rates for CD between 2002 and 2011 [22, 23].

The present study of the American population showed a significant decrease in both the total and urgent surgical rate for UC. A likely cause for this decline is improvement in medical management. Earlier biologic administration for moderate to severe disease and more aggressive management goals towards mucosal healing may have altered the natural history of the disease, leading to fewer surgeries. For ulcerative colitis, surgery is not usually considered until a patient has failed medical management or more rarely has developed toxic colitis or megacolon, a surgical emergency. The introduction of more timely and effective biologic therapies may have provided treatment options that decreased the need for surgery.

Table 3 Multivariable Cox proportional hazard analysis of post-op mortality

	Crohn's disease			Ulcerative colitis		
	O.R.	95% CI	*p* value	O.R.	95% CI	*p* value
Age	1.05	1.04–1.06	< 0.01	1.04	1.04–1.05	< 0.01
Female gender	0.91	0.77–1.08	0.27	0.96	0.84–1.09	0.50
Charlson Comorbidity Index	1.78	1.58–2.01	< 0.01	1.54	1.42–1.67	< 0.01
Protein-calorie malnutrition	2.22	1.83–2.69	< 0.01	1.02	0.90–1.17	0.72
Elective surgery	0.21	0.16–0.27	< 0.01	0.09	0.07–0.12	< 0.01
Highest vs. lowest income quartile	0.91	0.84–0.98	0.02	0.91	0.86–0.97	< 0.01
Payor	0.97	0.87–1.08	0.49	1.00	0.93–1.07	0.95
Hospital bed size	1.05	0.92–1.19	0.49	1.06	0.96–1.17	0.22
Private not-for-profit hospital	0.76	0.57–1.00	0.05	0.99	0.79–1.23	0.91
Private investor-owned hospital	0.65	0.45–0.93	0.02	1.18	0.91–1.52	0.21
Metropolitan teaching hospital	0.91	0.75–1.10	0.34	0.97	0.85–1.12	0.71
Rural hospital	0.53	0.35–0.82	< 0.01	0.99	0.74–1.32	0.94

The elective or non-elective basis of surgery is also important, as recent studies have demonstrated lower mortality for colectomies performed electively rather than urgently[24]. Explanations for the decreasing rates of urgent colectomy include improved ambulatory care with better options to escalate medical management, as mentioned prior, along with

Table 4 Multivariable Cox proportional hazard analysis of post-op mortality by urgent vs. elective surgery

	Elective surgery			Urgent surgery		
	O.R.	95% CI	*p* value	O.R.	95% CI	*p* value
Crohn's disease						
Age	1.05	1.04–1.07	< 0.01	1.05	1.04–1.06	< 0.01
Female gender	0.77	0.58–1.02	0.06	1.00	0.82–1.24	0.96
Charlson Comorbidity Index	2.22	1.82–2.70	< 0.01	1.66	1.42–1.94	< 0.01
Protein-calorie malnutrition	3.90	2.89–5.25	< 0.01	2.20	1.73–2.80	< 0.01
Highest vs. lowest income quartile	0.87	0.76–0.99	0.04	0.92	0.83–1.01	0.08
Payor	0.94	0.76–1.17	0.58	0.98	0.87–1.09	0.68
Hospital bed size	0.95	0.78–1.16	0.64	1.06	0.90–1.25	0.47
Private not-for-profit hospital	0.83	0.52–1.33	0.45	0.69	0.50–0.97	0.03
Private investor-owned hospital	1.09	0.60–1.97	0.79	0.54	0.34–0.83	< 0.01
Metropolitan teaching hospital	0.83	0.59–1.16	0.27	0.96	0.76–1.22	0.75
Rural hospital	1.38	0.76–2.51	0.29	0.26	0.14–0.48	< 0.01
Ulcerative colitis						
Age	1.05	1.04–1.07	< 0.01	1.04	1.04–1.05	< 0.01
Female gender	0.99	0.81–1.23	0.96	1.01	0.87–1.19	0.87
Charlson Comorbidity Index	1.78	1.53–2.06	< 0.01	1.51	1.38–1.66	< 0.01
Protein-calorie malnutrition	3.42	2.71–4.31	< 0.01	0.93	0.80–1.08	0.34
Highest vs. lowest income quartile	0.85	0.77–0.94	< 0.01	0.93	0.86–1.00	0.06
Payor	0.90	0.77–1.06	0.21	1.03	0.95–1.11	0.51
Hospital bed size	0.95	0.80–1.12	0.53	1.08	0.96–1.22	0.19
Private not-for-profit hospital	0.69	0.48–0.98	0.04	1.09	0.83–1.44	0.54
Private investor-owned hospital	1.11	0.72–1.71	0.65	1.26	0.92–1.73	0.15
Metropolitan teaching hospital	0.87	0.66–1.13	0.30	1.02	0.86–1.21	0.82
Rural hospital	0.70	0.38–1.30	0.26	1.08	0.78–1.48	0.65

treatment guidelines whose goal is deep remission and mucosal healing[25].

In this era of biologic therapy, a concern amongst surgeons has been that patients are spending too much time testing medical treatments to salvage severe colitis, only to arrive at surgery with higher risk of morbidity and mortality than in the prebiologic era. Encouragingly, the NRD data showed a significant decrease in post-operative mortality for UC. The decrease in mortality observed in our study could be due to improved preoperative medical management, better surgical techniques, increased use of laparoscopy, and closer post-operative monitoring. These possible contributors could be further explored with future studies. The overall post-operative mortality rates observed in the NRD database (5.8% in 2010 to 2.3% in 2017) are more promising than the 8.1% in-hospital post-operative mortality seen in a study of the New York state database from 2006 to 2013[26]. The New York study only included patients with UC and not CD and their patient population was slightly younger with more comorbidities. Our data included a larger group of patients and included mortality not just in hospital but for the 30-day post-operative period. We followed-up the concerning findings from the New York study using a larger database with a diversity of patients that more accurately reflects the national experience.

Crohn's disease, on the other hand, can affect any segment of the gastrointestinal tract and patients often require multiple surgeries in their lifetime, for complications such as fistula, abscess, bleeding, strictures, or perforation. More than half of CD patients will require surgery within 10 years of their diagnosis[27]. However, surgery in CD is associated with a high rate of recurrence at anastomoses[28], and risk of short gut with repeated surgeries. This study found a decrease in the total rate of surgery without a significant change in the rate of urgent surgery or post-operative mortality.

The decrease in overall rates of surgery could be due to the increased availability and usage of biologic therapy as mentioned for ulcerative colitis, but in the case of CD could also be secondary to increased use of advanced endoscopic interventions such as balloon dilation, and more advanced percutaneous techniques that can defer or prevent surgery in fistulizing CD patients. Although our study was not able to specifically look at these procedures, a pooled analysis showed that endoscopic balloon dilation was able to postpone surgical intervention in two-thirds of patients at 2 years[29], and a meta-analysis showed that 30% of patients who underwent percutaneous drainage of an intra-abdominal abscess were able to avoid surgery, with a mean follow-up of 26 months[30].

When evaluating patient and hospital-based variables affecting post-operative mortality, older age, higher Charlson Comorbidity Index, lower income, and non-elective admission were all individual predictors of post-operative mortality for both UC and CD. Both older age and higher Charlson Comorbidity Index are known to be associated with mortality. Meta-analysis of population-based IBD studies have shown higher post-operative mortality after urgent (as opposed to elective) intestinal resections for both UC and CD[31]. And even in countries with nationalized healthcare, lower income has been shown to be associated with increased mortality in surgical patients[32].

Limitations of this study included the inability to identify patients in the NRD receiving biologic therapy, as well as the retrospective and observational nature of the study. The duration of preoperative hospitalization and the events during this time could not be well described due to the limitations of the dataset. The improved outcomes may also be related to better multidisciplinary care in inpatient and outpatient settings, better preoperative optimization, and post-operative care of the patient rather than due to biologics alone. Finally, the dataset captures hospital encounters and tracks a single patient over a year in order to determine readmission, but over the multiyear time course of the study, decreased surgery may be a result of decreased reoperations in a small subgroup of patients as opposed to a generalized decrease in the risk of resection for IBD patients overall. This limitation affects the CD patients more so as a subset of patients could have required multiple resections over the study period[33]. The study is not able to comment on recurrent surgery or long-term need for surgery in CD or UC due to the inability of patients to be linked beyond the readmission event. These questions could be addressed in future studies.

Despite these limitations, this is the largest study to date to evaluate recent trends in IBD surgery and includes not only the overall trends in surgical rates, but more particularly urgent surgery and post-operative mortality over the last decade in the USA.

Using the NRD data, nationwide rates of bowel resections for UC and CD have significantly declined in both UC and CD patients between 2010 and 2017. There has also been a significant decrease in the rates of urgent surgery for UC, and post-operative 30-day mortality for CD and UC. This trend may be related to advances in medical therapy, more specifically the emergence and increased use of biologics.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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