



A retrospective comparison of outcomes for open vs. laparoscopic surgical techniques in pediatric ulcerative colitis

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Background: Ulcerative colitis (UC) is an aggressive disease in the pediatric population and a cause of significant, lifelong morbidity. The aim of this study is to compare surgical complications in pediatric patients undergoing laparoscopic *vs.* open surgical treatment for UC.

Methods: We queried the Kids' Inpatient Database (KID) for all cases of UC undergoing surgical treatment in 2009 and 2012. We identified patients who received total colectomy without proctectomy (n=413) or total proctocolectomy (n=196) and performed univariate and multivariate analyses comparing laparoscopic *vs.* open procedures.

Results: In pediatric UC patients undergoing total colectomy without proctectomy, open procedures were associated with more complications than laparoscopic, including fluid and electrolyte disorders (40% *vs.* 28%), surgical wound dehiscence (6% *vs.* 2%), septicemia (18% *vs.* 2%), and gastrointestinal disorders (16% *vs.* 7%) among others, all $P < 0.05$. Likewise, in patients with UC undergoing total proctocolectomy, there were more complications in open *vs.* laparoscopic technique, including increased transfusion requirements (25% *vs.* 7%, $P = 0.001$) and significantly more gastrointestinal upset, including nausea, vomiting, and diarrhea (11% *vs.* 1%, $P = 0.003$). In multivariate analysis, patients who underwent total colectomy with or without proctectomy had an increased risk of experiencing any complication when their procedure was performed in an open or non-elective fashion (all odds ratio > 2.4 ; all $P < 0.001$).

Conclusions: The laparoscopic approach was associated with significantly lower rates of surgical complications in pediatric patients undergoing total colectomy with or without proctectomy for UC. These findings demonstrate that laparoscopic technique compares favorably, and may be preferable, to the open approach in selected pediatric patients with UC.

Keywords: Laparoscopic; outcomes; inflammatory bowel disease (IBD); minimally invasive; ulcerative colitis (UC); pediatric surgery; minimally invasive surgery (MIS)

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Introduction

Ulcerative colitis (UC), a type of inflammatory bowel disease (IBD), is a chronic disease that can lead to significant lifelong morbidity (1,2). It has been estimated that up to 25% of new cases are diagnosed in the pediatric population (3,4). Among those diagnosed with UC, 20–30% will require major surgery over their lifetime and over 50% will require surgery within five years of diagnosis (5,6). The most common indications for surgery include severe colitis refractory to medical management, failure to thrive, colonic dysplasia, and malignancy (5,7).

Medical management is the mainstay for treatment, but surgical intervention plays a role in the more advanced or severe presentations. It is often reserved for those who are critically ill or are refractory to medical management, resulting in a high proportion of urgent or emergent cases (8). For those requiring surgery, the two most common surgical procedures in the US are total colectomy and total proctocolectomy (9). Despite recent advances in minimally invasive techniques, a significant number of these operations are still being performed in an open fashion (10).

In 2015, a retrospective analysis using the ACS NSQIP pediatric database compared surgical outcomes and postoperative length of stay (LOS) between laparoscopic (n=103) versus open (n=37) colectomy in a cohort of pediatric patients with UC. This study was able to demonstrate equivalent outcomes between the two methods. However, the authors felt their study was underpowered to detect a difference in surgical complications between the two cohorts (6). Many additional studies have demonstrated superior results in terms of outcomes when laparoscopy is employed, but these have largely been single institution studies or a single surgeon experience (11,12). The aim of our study is to provide a comprehensive analysis of surgical outcomes in pediatric patients undergoing laparoscopic and open surgical treatment for UC. We hypothesized that the laparoscopic approach in pediatric UC patients is significantly associated with a decrease in both postoperative length of stay as well as overall surgical complication rates. We present the following article in accordance with the STROBE reporting checklist (available at <http://dx.doi.org/10.21037/tgh-20-189>).

Methods

Nationwide data on U.S. children with UC that underwent

surgical treatment in the years 2009 and 2012 were obtained from the Agency for Healthcare Research and Quality (AHRQ)-sponsored Healthcare Cost and Utilization Project (HCUP) Kids' Inpatient Database (KID) (13). The KID is the largest publicly available all-payer pediatric inpatient care database in the U.S. and is released on a three-year cycle. It contains data from approximately 3 million pediatric discharges each year across 44 different states and is weighted for national estimates of roughly 7 million hospitalizations. Therefore, the KID is a powerful tool to analyze national trends in healthcare utilization, access, charges, quality, and outcomes for both common and rare pediatric conditions. The Institutional Review Board of the University of Miami waived the requirement for approval of this study since the KID contains de-identified, publicly available data.

Children (age ≤ 20 years) with a diagnosis of UC were identified in the KID by the International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis code(s) 556.0, 556.1, 556.2, 556.3, 556.6, 556.8, and 556.9. Patients who underwent an operation for colectomy or proctocolectomy were identified with the ICD-9-CM procedure codes 45.62, 45.81, 45.82, 46.20, 46.21, and 46.23 which differentiate between procedures performed by an open or laparoscopic approach. Patient status (elective *vs.* non-elective) was determined at the time of admission. Patients with both an open and laparoscopic approach were excluded as well as patients with a concurrent diagnosis code for colorectal malignancy. Nationwide population-based incidences were estimated from KID using the weight values provided in the data set for each case. Denominators for calculation of incidences were taken from the United States Census Bureau website (14).

The patient demographics, concurrent diagnoses, frequency of complications, length of stay, and treating hospital characteristics were compared. Categorical variables were compared using a chi-squared test, and continuous variables were compared using Student's *t*-test. Significance was set at $P < 0.05$. Multivariate regression models were constructed for identification of independent predictors of mortality. Variables with more than 20% missing data were not analyzed in the multivariate analysis. Results were weighted for national estimates according to HCUP standards. Statistical analyses were performed using SPSS Statistics version 24, IBM Corporation, Armonk, New York.

Table 1 Demographics

Characteristic	Total	
	N	%
Total	609	100
Type of admission		
Elective	300	49
Non-elective	309	51
Gender		
Female	295	48
Male	314	52
Race		
Caucasian	399	66
African American	38	6
Hispanic	57	9
Native American	#	<1
Other	23	4
Unknown	85	14
Insurance Status		
Medicaid	145	24
Private/HMO	420	69
Self-pay/no charge	#	1
Other	43	7
Household income by quartile*		
First quartile (\$1–24,999)	100	16
Second quartile (\$25,000–34,999)	138	23
Third quartile (\$35,000–44,999)	164	27
Fourth quartile (\$45,000+)	201	33
Bed size of hospital**		
Small	30	5
Medium	146	24
Large	407	67
Hospital location/teaching status		
Rural	12	2
Urban non-teaching	43	7
Urban teaching	527	87

Table 1 (continued)**Table 1** (continued)

Characteristic	Total	
	N	%
Surgical procedure		
Total abdominal colectomy	413	68
Total colectomy with proctectomy	196	32
Surgical technique		
Laparoscopic	377	62
Open	232	38

*, actual dollar amounts are approximations across all year ranges and are adjusted yearly for inflation; **, definition varies slightly by region; #, results censored due to KID reporting requirement for low number of cases.

Results

A nationwide total of 609 pediatric patients were identified who underwent surgical treatment for UC during the study period. The two surgical procedures performed included total abdominal colectomy (n=413; 68%) and total colectomy with proctectomy (n=196; 32%). The cohort was evenly distributed with respect to gender and elective *vs.* non-elective admissions. The majority of patients were Caucasian (n=399; 66%), had private/HMO insurance (n=420, 69%), and were treated in urban teaching hospitals (n=527; 87%). There was also a predilection to laparoscopic technique (n=377; 62%) in the cohort compared to open procedures. Additional demographic data is illustrated in *Table 1*.

Several variables in the cohort were found to be significantly associated with surgical approach and are demonstrated in *Table 2*. Patients were more likely to have laparoscopic operations at urban teaching hospitals than at rural or urban non-teaching hospitals (65% *vs.* 38%, $P<0.001$). Although rates of laparoscopic surgery were higher in patients with private/HMO and Medicaid, patients with private insurance had a significantly lower rate of open procedures versus patients with Medicaid (35% *vs.* 46%; $P=0.02$). Finally, no significant difference in the rates of open or laparoscopic procedures was detected by race. However, rates of laparoscopic procedures were still slightly higher in Caucasians (64% *vs.* 55% in African Americans) and it may be that this difference did not approach statistical

Table 2 Predictors of laparoscopic vs. open

Variable	Open	Laparoscopic	Total	P value
Type of admission				0.583
Elective	111	189	300	
Non-elective	121	188	309	
Total			609	
Gender				0.016
Male	134	180	314	
Female	98	197	295	
Total			609	
Race				0.418
Caucasian	143	256	399	
African American	17	21	38	
Hispanic	21	36	57	
Native American	#	#	#	
Other	#	18	27	
Total			523	
Insurance status				0.021
Medicaid	67	78	145	
Private/HMO	146	273	419	
Self-pay/no charge	#	#	#	
Other	14	23	37	
Total			609	
Household income by quartile*				0.233
First quartile (\$1–24,999)	44	56	100	
Second quartile (\$25,000–34,999)	57	81	138	
Third quartile (\$35,000–44,999)	63	101	164	
Fourth quartile (\$45,000+)	66	134	200	
Total			602	
Bed size of hospital**				0.133
Small	#	22	30	
Medium	48	98	146	
Large	163	243	406	
Total			582	

Table 2 (continued)

Table 2 (continued)

Variable	Open	Laparoscopic	Total	P value
Hospital location/teaching status				<0.001
Rural	#	#	13	
Urban non-teaching	28	15	43	
Urban teaching	185	342	527	
Total			583	
Region of hospital				0.179
Northeast	36	58	94	
Midwest	77	128	205	
South	67	83	150	
West	52	108	160	
Total			609	

*, actual dollar amounts are approximations across all year ranges and are adjusted yearly for inflation; **, definition varies slightly by region; #, results censored due to KID reporting requirement for low number of cases.

significance due to the small sample size of non-white races. The remainder of the associated variables are shown in Table 2.

In patients who underwent total abdominal colectomy without proctectomy, an open procedure was associated with a significantly longer median length of stay (14 vs. 11 days; $P < 0.01$). The open approach was also significantly associated with increased risk for fluid and electrolyte disorders (40% vs. 28%), GI disorders (16% vs. 7%), coagulopathy (9% vs. 3%), septicemia (18% vs. 2%), wound dehiscence (6% vs. 2%), and pneumonia (5% vs. 1%) as demonstrated in Table 3 (all $P < 0.05$).

Multivariate analysis was then performed to compare all statistically significant complications against relevant predictive variables (Table 4). Patients who underwent total colectomy without proctectomy, had significantly increased risk for any complication with an open approach (OR 2.75; $P < 0.001$). Similarly, non-elective admission also significantly increased the odds of experiencing a complication following any approach (OR 2.47; $P < 0.001$).

A similar analysis of patients who underwent total colectomy with proctectomy is displayed in Table 5. Univariate analysis revealed that open procedures were significantly associated with an increased risk for GI disorders (11% vs. 1%) as well as increased transfusion requirements (25% vs. 7%) (all $P < 0.005$). There was a statistically significant association between septicemia

and the laparoscopic approach but overall numbers were low. Multivariate analysis of this cohort also revealed that an open approach (OR 3.83; $P < 0.001$) and non-elective admissions (OR 3.91; $P < 0.001$) were significantly associated with increased odds of complications following surgery as shown in Table 6.

Discussion

UC is a relatively common, chronic disease that is a cause of serious morbidity in the pediatric population. This retrospective analysis represents the largest multi-institutional study to date which compares the outcomes of pediatric patients who underwent surgical treatment for UC. Additionally, while prior studies have demonstrated equivalency of the laparoscopic and open approaches, we have demonstrated for the first time that a laparoscopic approach to the treatment of this disease is associated with an improvement in post-surgical outcomes as well as shorter overall length of hospital stay in patients who undergo total colectomy without proctectomy.

It is estimated that over 150,000 children suffer from IBD in the United States alone (15). Although already a devastating diagnosis, the subpopulation diagnosed with UC often have significantly worse outcomes than their adult counterparts (16). Over 80% of all UC patients under 20 will be diagnosed with pancolitis and these patients often

Table 3 Univariate analysis—total colectomy without proctectomy*

Variable	Laparoscopic	Open	P value
Median length of stay (days)	11	14	0.01
Postoperative fluid and electrolyte disorders (yes)	79 (28%)	54 (40%)	0.018
Acute GI ulcer or bleed (yes)	37 (13%)	14 (10%)	0.394
pRBC transfusion (yes)	80 (29%)	48 (36%)	0.162
Postoperative GI disorders (yes)	20 (7%)	22 (16%)	0.004
Acute DVT (yes)	#(3%)	#(5%)	0.24
Coagulopathy (yes)	#(3%)	12 (9%)	0.014
Septicemia (yes)	#(2%)	24 (18%)	<0.001
Surgical wound dehiscence (yes)	#(2%)	#(6%)	0.047
Pneumonia (yes)	#(1%)	#(5%)	0.011
Pulmonary embolus or infarction (yes)	#(<1%)	#(1%)	0.7

*, all percentages rounded to the nearest whole percent; #, results censored due to KID reporting requirement for low number of cases.

Table 4 Multivariate analysis—total colectomy without proctectomy

Variable	Total colectomy		
	Total complications	Odds ratio	P value
Surgical procedure			
Open	46% (n=61)	2.75	<0.001
Laparoscopic	23% (n=65)		
Admission status			
Non-elective	37% (n=96)	2.47	<0.001
Elective	19% (n=30)		

require faster and further escalation of medical and surgical care than their adult counterparts (17). Due to the potential for severe complications from surgery the first line therapies for UC are primarily medical and include salicylates, antibiotics, steroids, and biologic agents (18).

However, surgical treatment of UC remains the cornerstone of therapy and nearly every patient diagnosed with UC will eventually require colectomy with ileal pouch-anal anastomosis (19). Surgery for UC falls into two broad categories, elective procedures and non-elective procedures. Elective procedures (one, two, or three stage operations) are generally for curative intent and are indicated when the patient has been diagnosed with early malignant disease or when the patient has become steroid dependent for adequate symptom control. Emergent (two or three stage operations)

procedures are performed for acute complications of the disease including toxic megacolon, perforation, and uncontrolled bleeding (5,8). This dichotomy between indications for surgery was evident in our cohort as the majority of proctocolectomies in our patient population (74%) were performed electively. Similarly, we observed that most colectomies (63%) were performed in patients who were admitted non-electively indicating that a subtotal colectomy in our cohort was primarily used to manage the acute complications of UC.

It is interesting to note that the difference in outcomes between open and laparoscopic surgery was minimal in the patients who underwent total colectomy with proctectomy. In fact, complications in this group overall were much lower than what was seen in those patients who underwent

Table 5 Univariate analysis—total proctocolectomy*

Variable	Laparoscopic	Open	P value
Median length of stay (days)	8	8	0.963
Postoperative fluid and electrolyte disorders (yes)	10 (10%)	19 (19%)	0.066
Acute GI ulcer or bleed (yes)	#(4%)	#(6%)	0.527
pRBC transfusion (yes)	#(7%)	24 (25%)	0.001
Postoperative GI disorders (yes)	#(1%)	11 (11%)	0.003
Acute DVT (yes)	0	0	–
Coagulopathy (yes)	#(2%)	#(<1%)	0.082
Septicemia (yes)	#(4%)	#(<1%)	0.044
Surgical wound dehiscence (yes)	#(1%)	#(4%)	–
Pneumonia (yes)	#(<1%)	#(1%)	0.314
Pulmonary embolus or infarction (yes)	0	0	–

*, all percentages rounded to the nearest whole percent; #, results censored due to KID reporting requirement for low number of cases.

Table 6 Multivariate analysis—total proctocolectomy

Variable	Total proctocolectomy		
	Total complications	Odds ratio	P value
Surgical procedure			
Open	33% (n=32)	3.83	<0.001
Laparoscopic	11% (n=11)		
Admission status			
Non-elective	41% (n=21)	3.91	<0.001
Elective	15% (n=22)		

colectomy alone. The reason for this is likely due to the majority of colectomies being performed for patients who were admitted due to non-elective indications while colectomy with proctectomy was reserved for patients with elective admissions. We were somewhat surprised to note that most colectomies performed for patients who were admitted non-electively in our cohort were performed laparoscopically (63%). This may indicate that surgeon proficiency and comfort with laparoscopic techniques has increased dramatically over the preceding decade and these techniques are now being used even in the treatment of complex cases. In fact, the majority of improvements in patient outcomes seen with laparoscopic technique occurred in the cohort of non-elective admissions. Therefore, our analysis appears to agree with recent

literature which indicates that the laparoscopic approach is appropriate as first line surgical therapy in even the sickest patients and should not be exclusively reserved for elective procedures (20).

In addition to the observed reduction in complications, laparoscopic total colectomies in our cohort were also significantly associated with a shorter median length of stay than open total colectomies. Length of stay is commonly used as a surrogate for cost and we did indeed observe a trend towards lower total cost of care in the laparoscopic group although it did not attain statistical significance due to high variability (results not shown). Historically, studies have cited the longer operative times of laparoscopic surgery as a potential drawback of this approach (21). As KID does not record procedure times, we were unable to comment on this in our analysis. However, more recent studies have been published which have found that, as surgeon experience increases, operative times for laparoscopic procedures have improved and become comparable to times seen in open procedures (22).

Our findings are not without limitations. KID is a strictly regulated source of pediatric inpatient information sampled across participating US hospitals. Still, there are possibilities that heterogeneity may exist in the data entry process due to institutional variability. Additionally, the analysis is retrospective, and as such we are limited to information coded in ICD-9-CM classifications. Furthermore, KID is a database of admissions and as such does not have information on prior treatments or surgeries that the

patients in our cohort may have received. This is significant as many UC patients have received steroids or biologics during the course of their treatment and prior studies have identified frequency and volume of steroid usage as well as recent use of anti-TNF α agents as being associated with worse outcomes following surgery (23,24). Lastly, while admissions are categorized as elective or non-elective, KID does not have the granularity to determine how soon after admission a patient undergoes an operation. Therefore, it is impossible to determine the precise medical acuity of patients at the time of operation and admission status is instead used as a surrogate.

Conclusions

UC in the pediatric population is the cause of significant morbidity and mandates eventual surgical intervention in all patients. We observed significantly lower length of stay in patients treated with laparoscopy compared to those who had an open procedure. The laparoscopic approach and elective surgery were both associated with a significantly lower rate of surgical complications in patients undergoing total colectomy with or without proctocolectomy. These findings demonstrate that laparoscopic technique is associated with more favorable outcomes compared to open total colectomy with or without proctectomy in pediatric UC patients.

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