Colonic Volvulus in the United States: Trends, Outcomes, and Predictors of Mortality

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Introduction: Colonic volvulus is a rare entity associated with high mortality rates. Most studies come from areas of high endemicity and are limited by small numbers. No studies have investigated trends, outcomes, and predictors of mortality at the national level.

Methods: The Nationwide Inpatient Sample 2002–2010 was retrospectively reviewed for colonic volvulus cases admitted emergently. Patients' demographics, hospital factors, and outcomes of the different procedures were analyzed. The LASSO algorithm for logistic regression was used to build a predictive model for mortality in cases of sigmoid (SV) and cecal volvulus (CV) taking into account preoperative and operative variables.

Results: An estimated 3,351,152 cases of bowel obstruction were admitted in the United States over the study period. Colonic volvulus was found to be the cause in 63,749 cases (1.90%). The incidence of CV increased by 5.53% per year whereas the incidence of SV remained stable. SV was more common in elderly males (aged 70 years), African Americans, and patients with diabetes and neuropsychiatric disorders. In contrast, CV was more common in younger females. Nonsurgical decompression alone was used in 17% of cases. Among cases managed surgically, resective procedures were performed in 89% of cases, whereas operative detorsion with or without fixation procedures remained uncommon. Mortality rates were 9.44% for SV, 6.64% for CV, 17% for synchronous CV and SV, and 18% for transverse colon volvulus. The LASSO algorithm identified bowel gangrene and peritonitis, coagulopathy, age, the use of stoma, and chronic kidney disease as strong predictors of mortality.

Conclusions: Colonic volvulus is a rare cause of bowel obstruction in the United States and is associated with high mortality rates. CV and SV affect different populations and the incidence of CV is on the rise. The presence of bowel gangrene and coagulopathy strongly predicts mortality, suggesting that prompt diagnosis and management are essential.

Colonic volvulus refers to torsion of the bowel around its own mesentery. This condition occurs in a long redundant colonic segment that has an elongated mesentery with a narrow base.[1,2] It is usually seen in the sigmoid colon, cecum, and less commonly, the transverse colon and splenic flexure.[3–5] Colonic volvulus is thought to account for 3.4% of all cases of bowel obstructions in the United States[5] and 10% to 50% in areas of higher endemicity, such as Africa, the Middle East, and South America[6,7] This geographic variation is thought to be due to anatomical differences[8,9]; differences in diet, altitude, cultural factors; and endemic infections.[10,11]

If left unattended, colonic volvulus can compromise the blood supply of the involved segment, leading to ischemia, gangrene, perforation, and death.[1,12] The mainstay

of sigmoid volvulus management has been through proctoscopic or colonoscopic decompression when feasible, followed by surgery either during the same admission or electively. Cecal volvulus is mostlymanaged surgically as the vastmajority of these cases are not amenable to endoscopic decompression.[13]

Most published literature on colonic volvulus is limited by small numbers accumulated over decades, with significant disparities in management techniques and outcomes. Moreover, these studies mainly come from areas of high endemicity where volvulus usually presents in a younger population and is thus associated with lower mortality rates[11] compared with countries of low endemicity such as the United States.

In the United States, the few available reports that investigated the incidence of colonic volvulus relative to other causes of bowel obstruction are either outdated or limited to large centers in specific regions. National-level data investigating incidences, practices trends, and outcomes in different hospital settings are thus lacking. Moreover, because prior data were limited by small sample sizes, a meaningful analysis of the predictors of mortality in sigmoid and cecal volvulus was never undertaken. This is a large retrospective analysis of colonic volvulus in theUnited States over a 9-year period, investigating trends, outcomes, and predictors of mortality of the different procedures performed for this disease entity.

METHODS

Patient Population and Data Source

Data were extracted from the Healthcare Cost and Utilization Project Nationwide Inpatient Sample (NIS) database from January 1, 2002 to December 31, 2010. We performed a retrospective analysis of colonic volvulus cases that underwent operative and nonoperative management. The NIS is the largest all-payer inpatient care database in the United States and contains information from nearly 8 million hospital stays each year across the country. The data set approximates a 20% stratified sample of American community, nonmilitary, nonfederal hospitals, resulting in a sampling frame that comprises approximately 95% of all hospital discharges in the United States. Data elements within the NIS are drawn from hospital discharge abstracts that allow determination of all procedures performed during a given hospitalization.14 Approval for the use of this database was obtained from the institutional review board of the University of California-Irvine Medical Center and the NIS.

Study Aims

The aim of our analysis was to investigate the management trends of colonic volvulus in the United States over a 9-year period. Mean patient age, comorbidity scores based on the Elixhauser-Van Walraven model,[15] and mortality rates for the different procedures were listed. The yearly number of admissions for all causes of bowel obstruction in the US was provided as a reference. These include small and large bowel obstruction due to adhesions, strictures, tumors, impaction, and hernia with obstruction. In the remainder of the analysis, we selected what we expected to be the largest groups of

cases, namely, cecal volvulus and sigmoid volvulus that underwent resection. Patient characteristics, surgical management in different hospital settings, and the associated mortality rates were examined. Surgical management includes the use of laparoscopy and the associated conversion rates and the use of an ostomy. The outcomes of surgical resection were listed for the 2 groups. Finally, we built predictive models for in-hospital mortality in patients undergoing resection for cecal volvulus and sigmoid volvulus. The model takes into account comorbidities present on admission, hospital and operative factors, excluding postoperative complications.

Inclusion Criteria

All patients with an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9 CM) diagnosis code for colonic volvulus (560.2) admitted urgently or emergently who underwent any of the procedures identified by the associated ICD-9 CM procedure codes were included in our analysis: enema decompression, endoscopic decompression, operative reduction, operative reduction and fixation, cecostomy or sigmoidostomy, resection with primary anastomosis, resection with the use of an ostomy, and total or subtotal colectomy. Laparoscopic modifier codes (54.21, 54.51) were used to identify laparoscopic cases for the years before 2009.

Because colonic volvulus has 1 single ICD-9 diagnosis code, we used the associated ICD-9 procedure codes to differentiate among cecal, sigmoid, and transverse colon volvulus that underwent resection. A binary model was used to ensure that no overlap occurred among identified cases and that each case is counted once.

Exclusion Criteria

Patients with a diagnosis of colonic volvulus who did not undergo any of the aforementioned procedures or who died before surgery were excluded from our analysis to minimize the risk of coding errors. Elective cases were excluded as our aim was to investigate management trends and outcomes in the acute setting. Missing variables listed in Tables 2 to 4 were also excluded from our analysis. These include data on ethnicity, hospital factors, and mortality.

Study Variables

Patient factors, such as age, sex, ethnicity, primary payer type, and comorbidities, provided by NIS were considered in our predictive models for mortality. The list of comorbidities is based on the Elixhauser model for comorbidity measures.[16] Presence of peritonitis or bowel gangrene identified by their respective ICD-9 codes were also used in our predictive model. Hospital factors, such as teaching status, location, and size, were considered in our model, as previous reports have underlined differences in mortality rates in sigmoid volvulus cases managed in different hospital settings.[17] Operative factors, such as the use of stoma, laparoscopic versus open surgery, and emergent versus semielective surgery, were considered in our model-building routine as well. Cases that underwent endoscopic decompression on admission followed by surgery during the same hospitalization were considered in the semielective surgery group. Those who underwent surgery on admission without prior endoscopic decompression were considered in the emergent surgery group. In the cecal volvulus model, we excluded the semielective versus emergent surgery variable, as these cases are usually not amenable to endoscopic

decompression. This list of variables we hypothesized would predict that mortality was chosen a priori.

Statistical Analysis

All statistical analyses were conducted using SAS, version 9.3, and the R Statistical Environment. The LASSO algorithm for logistic regression[18] was used to identify variables predictive of mortality in patients who underwent resection for sigmoid or cecal volvulus in a complete case analysis. Ten-fold cross-validation together with the 1-SE rule was used to determine the model size (number of variables) to control for overfitting.[19] In contrast to the classic multivariate logistic regression in which odds ratios are independent of each other and cannot be added together to predict mortality, LASSO assigns a coefficient to each predictor. These coefficients can be added together to calculate the predicted inhospital mortality risk for each individual. For a coefficient total of x, the inhospital mortality risk is ex/(1 + ex). Separate models for sigmoid and cecal volvulus were built. The receiver operating characteristic curve (ROC) and C-statistic were used to describe how well our model predicts mortality.

RESULTS

From 2002 to 2010, an estimated 3,351,152 patients were admitted with a bowel obstruction in the United States. Colonic volvulus accounted for 63,749 cases (1.90%). Admissions for bowel obstruction increased steadily from 2002, reaching a peak in 2008 and then decreasing over the last 2 years of the study period, whereas the number of admissions for colonic volvulus increased over the last 3 years of the study period. This increase was mainly driven by admissions for cecal volvulus that showed an upward trend, increasing by an average of 5.53% per year over the study period. Sigmoid volvulus cases remained relatively stable over the study period (Table 1).

Nonsurgical methods, such as enema or endoscopic decompression for sigmoid volvulus, not followed by surgery during the same admission were used in 16.6% of cases. Enema was used infrequently, primarily in relatively elderly patients with high comorbidity scores. The use of endoscopic decompression alone showed a relatively stable incidence and had an associated mortality of 6.4% (Table 1).

Surgical methods not involving resection remained relatively infrequent in the acute setting. Surgical detorsion without fixation (4.2% of surgical cases) was associated with a relatively high mortality of 7.8%, considering the younger age of this population. Surgical fixation such as cecopexy or sigmoidopexy (3.3% of surgical cases) was performed in patients with relatively low comorbidity scores and was associated with lowmortality rates. Enterostomy procedures such as cecostomy or sigmoidostomy (3.3%) were used in relatively sick patients and had a 13.0% mortality rate (Table 1).

Among cases managed surgically, resection was the most commonly performed procedure in 89.3% of cases. Resective procedures were performed for cecal, sigmoid, synchronous cecal and sigmoid, and transverse colon volvulus. A subtotal or total colectomy was required in 16.0% of sigmoid volvulus cases. In these cases, patients had relatively high associated comorbidity scores and mortality rates (14.6%). It is interesting to note that we identified 576 cases of synchronous cecal volvulus and sigmoid volvulus. Patients in this group had the highest comorbidity scores and a

mortality rate of almost 18%. The other interesting finding is the 597 identified cases of transverse
colon volvulus: these had high comorbidity scores and mortality
rates considering again the younger age group of this population
(Table 1).

Laparoscopic techniques were rarely applied in the management of colonic volvulus, accounting for 3.7% of surgical cases. However, the use of laparoscopy has increased over the study period, especially in the last 3 years. Laparoscopy was used in relatively younger patients with lower comorbidity scores and the associated mortality rates were lower than their corresponding open counterpart.

TABLE 1. National Estimates* of Cases Performed Per Year for Colonic Volvulus. Mean Age, Comorbidity Score,† and Mortality Rates Per Procedure Type Are Presented

Procedure	Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	Mean Age	Comorbidity Score	Mortality, %
Barium enema decompression		10	0	0	5	15	5	14	0	4	53	76	7.09	0
Endoscopic decompression		1,284	1,198	1,222	1,182	1,296	950	1,140	1,144	1,129	10,545	72	5.92	6.41
Operative detorsion only (cecal or sigmoid)	Open	220	285	241	207	244	184	242	232	207	2,062	53	4.67	7.76
	Laparoscopic	18	10	9	11	23	9	26	29	10	145	51	3.83	0
Detorsion and fixation only (cecopexy, sigmoidopexy, or fixation of the transverse colon)	Open	226	206	221	205	99	165	225	119	133	1,599	60	3.35	3.43
	Laparoscopic	14	26	18	6	20	18	23	16	26	167	58	2.66	3.01
Enterostomy (cecostomy or sigmoidostomy)	Open	188	177	161	202	166	236	140	233	162	1,665	68	7.57	13.09
	Laparoscopic	5	5	0	5	19	9	10	10	5	68	72	3.21	7.02
Resection for cecal volvulus	Open	2,141	1,902	2,187	2,313	2,572	2,456	3,166	3,007	2,974	22,718	63	4.79	6.65
	Laparoscopic	15	30	45	64	82	77	77	99	185	674	58	2.60	4.90
Resection for sigmoid volvulus	Open	2,136	2,070	1,923	2,053	2,086	2,039	1,973	2,037	2,070	18,387	71	7.49	9.73
	Laparoscopic	30	56	25	58	47	72	86	238	221	833	67	5.85	1.80
Resection for metachronous cecal volvulus and sigmoid volvulus	Open	46	71	60	70	60	86	68	62	43	566	67	8.94	17.84
	Laparoscopic	0	0	0	5	0	0	0	0	5	10	62	3.00	0
Resection for transverse colon volvulus	Open	33	56	58	88	40	44	135	66	67	587	59	6.10	16.70
	Laparoscopic	0	0	0	0	0	0	5	5	0	10	54	4.00	0
Subtotal or total colectomy	Open	383	362	459	370	455	433	397	295	428	3582	65	7.63	14.63
	Laparoscopic	14	9	0	15	15	9	11	0	5	78	59	6.33	11.54
Total cases of colonic volvulus		6,763	6,463	6,629	6,859	7,239	6,792	7,738	7,592	7,674	63,749			
Total cases of bowel obstruction (all causes)		345,567	344,250	359,243	370,420	373,616	377,206	403,039	398,525	379,286	3,351,152			

*These numbers based on NIS agree with the National Hospital Discharge Survey. A binary decision model was used to ensure that no overlap of cases occurs during data analysis. Each case represents a single occurrence.
†Comorbidity scores are based on the NIS comorbidity variables and are calculated using the Van Walraven model.
NIS indicates Nationwide Inpatient Sample.

FIGURE 1. Age histogram per sex for cecal volvulus and sigmoid volvulus.

TABLE 2. Demographic Characteristics and Comorbidities for Sigmoid and Cecal Volvulus Cases That Underwent Resection

N	Sigmoid Volvulus 19,220	Cecal Volvulus 23,392
Age, yr	71 (62–82)	63 (52–78)
Sex, %		
Male	65.5	27.0
Female	34.5	73.0
Ethnicity (%)		
White	53.3	66.8
Black	14.9	4.9
Hispanic	4.6	2.2
Asian or Pacific Islander	0.9	0.2
Native American	0.4	0.4
Other	1.8	1.1
Missing	24.1	24.4
Primary payer type (%)		
Medicare	49.6	38.1
Medicaid	4.3	3.5
Private including HMO	10.3	26.5
Self-pay	1.6	2.4
No charge	0.1	0.2
Other	1.0	1.6
Missing	33.1	27.7
Comorbidities (%)		
Anemia	16.6	11.7
Congestive heart failure	16.8	10.4
Chronic pulmonary disease	16.6	20.6
Diabetes	17.2	9.5
Hypertension	43.9	36.1
Liver disease	0.8	1.4
Fluid and electrolyte disorders	48.1	36.4
Obesity	2.7	2.4
Renal failure	5.8	4.6
Weight loss	12.9	9.9
Neurological disorder or paralysis	31.3	8.0
Comorbidity scores	7.4 (3.00–12.00)	4.7 (0.00–8.00)

Continuous variables such as age and comorbidity scores are reported as mean and interquartile range; categorical variables (sex, ethnicity, payer type, and comorbidities) are reported as percent proportions.

HMO indicates health maintenance organization.

Laparoscopy was most commonly used in cases involving fixation of the colon (Table 1).

Among patients with sigmoid or cecal volvulus who underwent resection, mean age was higher in the sigmoid volvulus group and male patients accounted for the majority of cases, whereas female sex was more predominant in the cecal volvulus (Table 2). Looking at the age histogram, the incidence of sigmoid volvulus peaked in the mid-70s for both women and men. This in contrast to the age histogram of cecal volvulus in which women demonstrated 2 incidence peaks: 1 in the mid-50s and another in the late 70s. Moreover, the frequency of cecal volvulus in women seems to increase rapidly starting in their early 30s (Fig. 1).

African Americans were present at a higher frequency in the sigmoid volvulus group. Patients with sigmoid volvulus group tended to have higher incidence of comorbidities, such as anemia, congestive heart failure, hypertension, and fluid and electrolyte disorders. Perhaps, the major difference was in the frequency of diabetes and neuropsychiatric disorders including dementia and paralysis related to cerebrovascular events. Comorbidity scores were higher in the sigmoid group, reflecting a sicker patient population (Table 2).

Looking at hospital characteristics in the sigmoid and cecal volvulus groups,we observe that the majority of cases were performed in nonteaching, urban, and large hospitals. The use of laparoscopy was similar in the 2 groups; however, conversion rates were higher in cases of cecal volvulus. A stoma was required in almost half of sigmoid volvulus cases that underwent resection, whereas this was much lower in cecal volvulus cases (Table 3).

The management of sigmoid volvulus and the associated outcomes were similar in different hospital settings. The small differences observed were in the higher use of laparoscopy and the lower associated conversion rates when comparing urban hospitals with rural hospitals. Stoma use and mortality rates were similar in different hospital settings (Table 3). In cecal volvulus, the use of laparoscopy was more common in urban than in rural hospitals. Stoma use was higher in teaching than in nonteaching hospitals and higher in large hospitals than in medium and small hospitals. Mortality rates were similar in different hospital settings (Table 3).

Looking at surgical outcomes in sigmoid and cecal volvulus cases that underwent resection, we note a longer length of stay in the sigmoid volvulus group and a higher total charge. Mortality was 9.4% for sigmoid volvulus and 6.7% for cecal volvulus. Of note is that anastomotic complications were high in both groups. The incidence of respiratory failure, pneumonia, acute renal failure, urinary tract infection, urinary retention, and deep vein thrombosis was higher in the sigmoid volvulus group (Table 4).

The LASSO algorithm was applied to cases that underwent resection for sigmoid volvulus and identified the presence of peritonitis and bowel gangrene as the strongest predictors of mortality. This was followed by the use of an ostomy and coagulopathy. Other factors, such as the presence of chronic kidney disease, age more than 70 years, chronic pulmonary or cardiac disease, and fluid and electrolyte disorders, were also found to predict mortality (Table 5). Performing surgery on an emergent or semielective basis and the use of laparoscopy were not found to affect mortality. Hospital factors were not found to impact mortality. The area under the curve (AUC) for the predictive model was 0.74 (Fig. 2).

TABLE 3. Use of Laparoscopy, Conversion Rates, Use of Ostomy and Mortality Per Hospital Type, Location, and Bed Size

	Sigmoid Volvulus (N = 19,220)					Cecal Volvulus (N = 23,392)				
	All (%)	Use of Laparoscopy, %	Conversion Rate, %	Stoma use, %	Mortality, %	All, %	Use of Laparoscopy, %	Conversion rate, %	Stoma use, %	Mortality, %
Hospital type										
Teaching	41.5	7.2	18.8	49.8	8.8	41.8	7.0	33.1	14.2	6.1
Nonteaching	57.9	5.9	17.2	49.3	10.0	57.6	7.2	31.5	8.6	7.1
Missing	0.6					0.6				
Location										
Urban	84.8	6.8	16.8	50.0	9.5	84.5	7.7	33.0	11.1	6.5
Rural	14.6	4.4	28.0	46.5	9.6	14.9	3.8	22.2	10.1	7.4
Missing	0.6					0.6				
Bed size										
Small	8.7	7.7	23.1	45.9	5.9	9.7	9.3	32.6	8.9	7.0
Medium	17.7	8.2	21.0	50.3	9.4	18.2	9.8	33.3	8.9	7.8
Large	39.9	8.6	15.7	46.4	8.0	44.0	8.6	33.5	12.0	6.2
Missing	33.7					28.1				

TABLE 4. Surgical Outcomes for Sigmoid Volvulus and Cecal Volvulus of Patients Who Underwent Resection

N	Sigmoid Volvulus (N = 19,220)	Cecal Volvulus (N = 23,392)
Total charge ($)	80,352 (33,685–90,800)	68,935 (26,712–73,525)
Length of stay, d	15 (8–18)	11 (6–13)
Mortality		
Died	9.4	6.7
Missing	0.28	0.04
Postoperative complications		
Cerebrovascular accident	0.1	0.2
Cardiac complications	2.7	3.1
Respiratory failure	13.6	11.9
Pneumonia	10.0	7.5
Ileus/bowel obstruction	20.5	19.4
Anastomotic complications*	15.8	15.2
Acute renal failure	14.5	11.8
UTI	18.1	8.9
Urinary retention	3.2	2.3
Postoperative bleeding	2.6	3.0
Wound complications	6.3	6.6
DVT	1.0	0.6

Continuous variables such as total charge and length of stay are reported as mean and interquartile range; categorical variables are reported as percent proportions.

*Including anastomotic leak, fistula, and intra-abdominal abscess.

DVT indicates deep vein thrombosis; UTI, urinary tract infection.

Looking at cecal volvulus, the LASSO algorithm identified coagulopathy as the strongest predictor of mortality, followed by age more than 60 years. The presence of peritonitis and bowel gangrene, the use of an ostomy, and several comorbidities listed in Table 5 were also found to be associated with worse outcomes. Again, the use of laparoscopy and hospital factors were not found to affect mortality. Interestingly, female sex, private insurance, and hypertension were found to be protective against mortality relative to the variables identified in the model. The AUC for the predictive model was 0.82 (Fig. 3).

DISCUSSION

Colonic volvulus is a rare cause of bowel obstruction in the United States, accounting only for 1.9% of admissions which is in the range of previously published studies in the United States that attributed 1.2% to 20% of all intestinal obstructions to colonic volvulus.[20–23] The wide variation of incidence observed in previous studies is due to demographic differences among the study populations.[24] This was observed in our

results with a higher incidence of sigmoid volvulus in African Americans. The latter group United States and the associated high number of sigmoidectomies[34] may explain this finding. In contrast, we observed an increase in cecal volvulus cases. Although this is neither supported nor refuted by our data, one may try to explain this observed trend by the parallel increase of screening colonoscopies as a result of large colorectal cancer screening campaigns[35,36] and an overall increase in the use of laparoscopic techniques. Air insufflation during colonoscopy leads to cecal dilatation and may play a role in the development of cecal volvulus.[37,38] During laparoscopy, pneumoperitoneum, patient positioning, lateral tilting of the operating table, and mobilization of parts of the right colon have been implicated as causative factors in patients with a mobile cecum.[39,40]

Reports from the United States identified nearly equal proportions of cecal volvulus and sigmoid volvulus.[5,13,41] Because of limitations of the NIS database, these proportions are difficult to obtain. However, if we consider all cases of endoscopic decompression for sigmoid volvulus to represent definitive treatment with no recurrence, and moreover, if we consider cases of detorsion, fixation, or enterostomy to be all performed for sigmoid volvulus, we find cecal volvulus to account for at least 38% of all volvulus cases.

Cecal volvulus and sigmoid volvulus demonstrate different demographics. While sigmoid volvulus was more common in elderly men, the majority of patients with cecal volvulus were younger women. Our findings are in line with previously reported series.[5,6,13,25,42] Sigmoid volvulus in the United States affects an older population compared with other countries where it is more endemic.[43,44] The age histogram shows rising frequencies of cecal volvulus in women in child-bearing age. This confirms previous reports that described a link between cecal volvulus and pregnancy when the gravid uterus comes out of the uterine cavity displacing the cecum, thereby elongating its mesentery and making it more prone to torsion during or immediately after delivery.[45,46] The incidence peak of cecal volvulus observed inwomen in their mid-50s may also be due to previous pelvic surgery. This corresponds to the age group where many women in the United States have already had a hysterectomy.[47] Previous pelvic surgical procedures may create a mobile cecum or lead to postoperative adhesions that may create an axis around which

TABLE 5. Predictors of Mortality of Patients With Sigmoid Volvulus and Cecal Volvulus Who Underwent Resection Based on the LASSO Algorithm

	Coefficient	LASSO OR
Sigmoid volvulus		
Intercept	−2.95	0.05
Peritonitis/bowel gangrene/necrosis	0.61	1.84
Stoma use	0.46	1.58
Coagulopathy	0.46	1.58
Chronic kidney disease	0.24	1.27
Age >70 yr	0.17	1.18
Chronic pulmonary disease	0.13	1.14
Congestive heart failure	0.04	1.04
Fluid and electrolytes disorders	0.01	1.01
Cecal volvulus		
Intercept	−3.45	0.03
Coagulopathy	0.91	2.49
Age >60 yr	0.71	2.04
Metastatic cancer	0.54	1.71
Chronic kidney disease	0.43	1.53
Congestive heart failure	0.39	1.47
Stoma use	0.35	1.42
Fluid and electrolyte disorders	0.32	1.38
Weight loss	0.20	1.22
Pulmonary circulation disorder	0.17	1.18
Peritonitis/bowel gangrene/necrosis	0.12	1.13
Chronic pulmonary disease	0.07	1.07
Hypertension	−0.04	0.96
Private insurance including HMO	−0.08	0.92
Female	−0.15	0.86

These coefficients can be added together to calculate the predicted inhospital mortality risk for each individual. For a coefficient total of x, the inhospital mortality risk is $e^x/(1 + e^x)$.

HMO indicates health maintenance organization; LASSO, least absolute shrinkage and selection operator; OR, odds ratios.

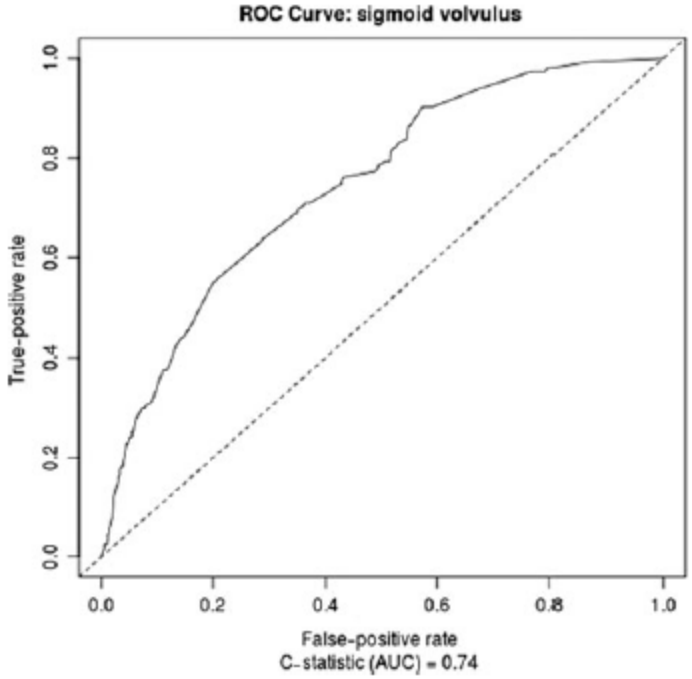

FIGURE 2. ROC curve and C-statistic (AUC) describing the discriminative power of the mortality predictive model for sigmoid volvulus cases.

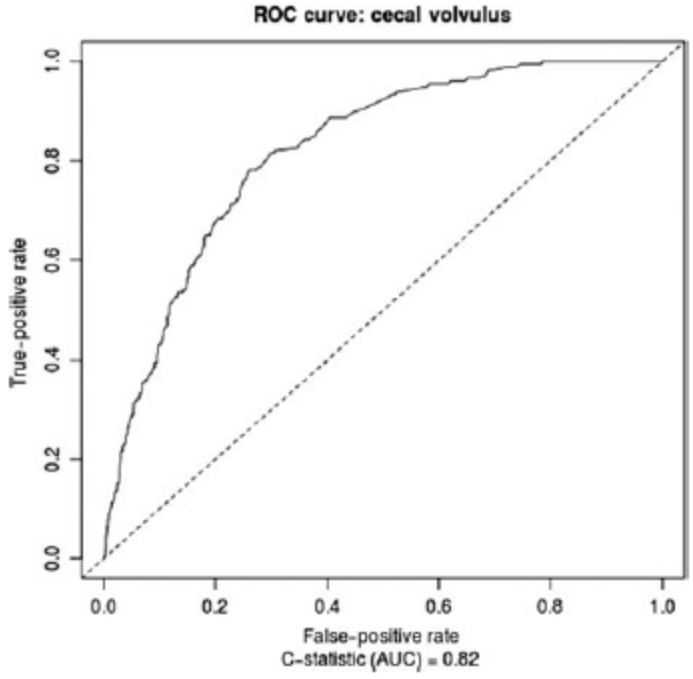

FIGURE 3. ROC curve and C-statistic (AUC) describing the discriminative power of the mortality predictive model for cecal volvulus cases.

the cecum can rotate.[42,48,49] The lower incidence of sigmoid volvulus in women can be explained anatomically by the fact that women have a capacious pelvis with lax abdominal musculature that can accommodate and allow the untwisting of a floppy sigmoid.[50] The previously observed high incidence of sigmoid volvulus in patients with neuropsychiatric diseases[12,13,24,51–53] and diabetes54 is also confirmed by our results and points toward an acquired pathology.

Examining the different management methods in colonic volvulus, we observed that nonsurgical methods of colonic decompression are not commonly used as the sole treatment measure and are usually followed by more definitive surgery. Contrast enema in the management of colonic volvulus was historically used for diagnostic and therapeutic reasons.[4,5,13,53,55,56] The rare identified cases were older patients with multiple comorbidities, who probably were not good surgical candidates. Colonoscopic decompression which has a success rate of 70% to 90%[12,29,53,57] is mainly used for sigmoid volvulus, as it is mostly unsuccessful for cecal volvulus.[5,13,58] It is, however, considered a temporizing measure allowing surgery to be performed on either an elective or a semielective basis after correction of underlying fluid and electrolyte imbalance.[5,30] It is rarely advocated as a definitive treatment because of the associated high-recurrence rates of 20% to 70%.[1,4,30,53,57,59,60] Moreover, because the mortality rate for recurrent sigmoid volvulus presenting emergently can be as high as 33%,[53] several authors advocate resection as a form of definitive management after initial colonoscopic decompression.[53,60]

Surgical management of colonic volvulus can be broadly divided into resective versus nonresective procedures. The use of nonresective procedures such as detorsion with or without fixation or enterostomy seems to be infrequent in the acute setting according to our results. The reason for these findings are the high recurrence rates after these procedures which are reported to be 22% to 25% for detorsion of cecal volvulus,[61,62] 20% to 30% for cecopexy,[6,63] 9% to 44% for simple detorsion of sigmoid volvulus,[6,64,65] and 28.5% for sigmoidopexy.[25,65] In contrast to previously published series, we found that operative detorsion with or without fixation was used in younger populations. This may be explained by younger patients' refusal to have a resective procedure or in certain cases because the overall condition of the patient would not permit a colonic resection.[53,66] Sigmoidostomy and cecostomy with the use of a decompression tube were uncommonly performed. These procedures that were more common decades ago[67] seem to have fallen out of favor as they are associated with high morbidity and recurrence rates.[68] Furthermore, it seems from our analysis that their use is limited to patients not suitable for resection.

Resective surgery with or without stoma was found to be the most commonly performed surgical procedure in the acute setting. Although a right hemicolectomy is usually sufficient to treat cecal volvulus, the extent of resection for sigmoid volvulus has been the subject of debate.69 Recurrence has been reported after resection for sigmoid volvulus depending on the extent of colonic involvement; patients whose disease is limited to the sigmoid colon recur less than those with associated megacolon and colonic atony.[70,71] The other reason for performing an extended resection is that gangrene can

extend beyond the area of constriction in a patchy and ill-defined pattern.[43] This likely explains the significant proportion of cases that required a total or subtotal colectomy in our results.

The high use of stoma during resective surgery for sigmoid volvulus as observed in our results is in line with previous reports[13,59] and can be explained by the high fecal and bacterial content of the left colon[72] and the advanced age and comorbidities of patients with sigmoid volvulus.[59] Although performing a primary anastomosis in the setting of gangrene may lead to a high rate of anastomotic leak, high fecal content load should not be the only reason to perform a stoma, as a primary anastomosis may be safe in this setting.[73] The use of stoma was also observed in right hemicolectomy for cecal volvulus. Cecal volvulus often presents late and sometimes represents a diagnostic challenge delaying surgical treatment.[49,68] The thin cecal wall is especially sensitive to dilatation and perforation, and a delay in diagnosis and management can be detrimental.

Mortality rates of the different surgical procedures are in line with previously reported data.[5,6,10,13,57,59,74,75] Compared with older data, mortality rates did not change significantly. Cases managed laparoscopically seemed to have lower mortality rates. However, the use of laparoscopy was observed in patients with lower comorbidity scores, and these procedures are usually performed on a semielective basis after initial endoscopic decompression.[46,76,77] In contrast to previously published data,[43,78] we did not identify the performance of semielective surgery after initial endoscopic decompression to protect against mortality. It may be the case in which this effect may be masked by other factors that have a higher impact on mortality. Delaying surgery after successful colonoscopic decompression to correct underlying fluid and electrolyte imbalance has been found to decrease mortality rates.[60] The effect of fluid and electrolyte imbalance on mortality rates was not very pronounced.

The presence of bowel gangrene and peritonitis was a strong predictor of mortality from cecal volvulus and sigmoid volvulus. In sigmoid volvulus, this finding alone doubled mortality rates. This was also seen for cecal volvulus cases to a lower extent. These finding echo findings from smaller observational studies[6,24,25,43,52,60,62,79,80;] however, most of these studies were small and did not achieve statistical significance. The use of stoma was also found as a predictor of mortality; however, this could be a surrogate to bowel gangrene and peritonitis. Coagulopathy was another strong predictor of mortality. The definition of coagulopathy in NIS includes the presence of disseminated intravascular coagulopathy that occurs in the setting of sepsis and septic shock. This suggests that prompt management is essential in the management of colonic volvulus.[65] The effect of age on mortality was less pronounced in sigmoid volvulus than in cecal volvulus. Again, this is in line with previous findings that noted higher mortality rates for sigmoid volvulus in patients older than 70 years.[59,79,81] The AUC of the ROC for both sigmoid and cecal volvulus groups reflected good predictive power, and the 10-fold cross validation performed ensures that these models can be generalized beyond the sample analyzed.

The main limitation of this study lies in its retrospective nature and its inherent biases. The potential for coding errors exist when using an administrative database.[82] The incidence of volvulus could be slightly underestimated as we excluded patients who died before surgery and the rare cases that may have detorsed spontaneously as previously reported.[13,64,69,79,83] One ICD-9 diagnosis code for colonic volvulus exists and hence

differentiation between cecal volvulus and sigmoid volvulus in cases of operative detorsion or fixation was not possible. Mortality rates could be higher than observed, as the NIS only provides information related to the index hospital stay and hence 30-day mortality and mortality rates are not available. Because each record in NIS is for a single hospitalization, there could be multiple records for an individual if that individual had several hospitalizations. This would affect the number of admissions for sigmoid volvulus that may recur after nondefinitive treatment. The inability to track individual cases did not allow us to calculate recurrence rates for sigmoid volvulus cases that underwent initial endoscopic
decompression.

CONCLUSIONS

This is the largest and only population-based study investigating the trends and outcomes of colonic volvulus at a national level and the only study with a strong predictive model for mortality. Colonic volvulus is a rare cause of bowel obstruction in the United States. Although the incidence of sigmoid volvulus appears stable, increasing numbers of cecal volvulus were observed. Sigmoid and cecal volvulus affect different populations and when present synchronously lead to high mortality rates. Volvulus of the transverse colon is rare and associated with high mortality rates. Resection is the most commonly performed procedure for colonic volvulus in the acute setting. The mortality rate of surgical cases is related to patients' age and comorbidities and is mostly driven by bowel viability and the presence of coagulopathy. This suggests that time is of the essence in the management of this condition.

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