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Research Paper

Factors affecting minimally invasive surgery utilization during elective colectomies for diverticular disease in the United States

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HIGHLIGHTS

- Most elective colectomies for diverticular disease in the United States are done with minimally invasive surgery (MIS.)
- Hospital bed size or teaching status is no longer associated with differences in MIS use.
- Patients with private insurance are more likely to have an MIS operation.
- Racial disparities in MIS use persist, even after adjusting for insurance status.

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ABSTRACT

Background: Compared with open surgery, minimally invasive surgery (MIS) has been shown to have improved outcomes when treating diverticular disease. This study aimed to analyze recent trends in MIS utilization for elective colectomy for diverticular disease and to identify individual variables and hospital characteristics associated with MIS utilization.
Methods: This population-based study examined individuals from the National Inpatient Sample who underwent elective colectomy for diverticular disease from 2016 to 2019.
Results: Hospitals in the Midwest used MIS less than those in other geographic regions. Rural hospitals used MIS less than urban hospitals. Hospital bed size and teaching status were not associated with differences in MIS utilization. Patients with private insurance were more likely to have an MIS operation. There was also a racial disparity in MIS utilization, even after adjusting for insurance status.
Conclusions: While there is no longer any variance in MIS utilization based on hospital bed size or teaching status, disparities concerning patient race remain, even after adjusting for insurance status. Further investigation is needed to determine the roots of these disparities.

Introduction

Diverticular disease and its complications remain quite prevalent in the West, accounting for over a million outpatient visits annually with an annual economic burden of $3 billion in the United States alone [1]. Although indications for surgery have become more conservative over time, elective colectomy remains an important treatment option for many patients. Surgery has been shown to reduce, but not eliminate, the risk of recurrent diverticulitis [2]. In addition, studies have shown that elective colon resections may improve the quality of life of patients with diverticular disease [3].

While laparoscopy was previously utilized for other operations such as cholecystectomy, laparoscopy for colon resections was first described in 1991 [4]. Subsequently, studies have been conducted to establish the safety and technical aspects of the procedure. Furthermore, many studies have been done comparing minimally invasive surgery (MIS) to open surgery. Compared with open surgery, minimally invasive surgery (MIS) has been shown to result in improved outcomes, including decreased morbidity and length of hospital stay, when treating diverticular disease [5].

Despite its advantages, the use of MIS for colectomies varies in the United States. The adoption of MIS techniques for colon resections has increased over the past 20 years. In 2002, the overall rate of MIS utilization for diverticular disease in the elective setting was just 6.9 % [6]. A

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study using National Inpatient Sample (NIS) from 2004 to 2011 found an MIS utilization rate of 13.7 % [7]. In a study examining data from 2009 to 2012, MIS utilization had increased to 47.7 % [8]. Despite its increasing usage, the benefits of MIS have not been experienced uniformly. One study examined common surgical procedures that can be performed laparoscopically and found that the largest racial disparity was with colectomies [9]. Another study examining the NIS between 2009 and 2012 found that MIS utilization was significantly associated with hospital size, teaching status and urban location [10]. In this study, we aimed to examine recent trends in the utilization of MIS for elective colectomy for diverticular disease in the United States and to identify with identifying individual variables and hospital characteristics associated with MIS utilization.

Methods

Data source and patients

This population-based study included individuals who underwent elective colectomies for diverticular disease in the United States. The Healthcare Cost and Utilization Project (HCUP) National Inpatient Sample (NIS) is the largest public inpatient database, representing approximately 20 % of hospital discharges in the United States. The NIS was analyzed using data from 2016 to 2019 from patients who underwent colonic resection for diverticular disease. The International Classification of Disease, tenth edition (ICD-10) codes used to identify patients with diverticular disease were K57.9, K65, K57.32, K57.31, K57.30, K57.33, K57.20 and K57.80. The ICD-10 procedure codes used to identify open colectomies were 0DTE0ZZ, 0DTE7ZZ, 0DTG0ZZ, 0DTG7ZZ, 0DTM0ZZ, 0DTM7ZZ, 0DTN0ZZ and 0DTN7ZZ. ICD-10 procedure codes used to identify minimally invasive colectomies were 0DTE4ZZ, 0DTE8ZZ, 0DTG4ZZ, 0DTG8ZZ, 0DTGFZZ, 0DTM4ZZ, 0DTM8ZZ, 0DTMFZZ, 0DTN4ZZ, 0DTN8ZZ and 0DTNFZZ. For the purposes of this study, we did not differentiate between laparoscopic and robotic colectomies. Patients aged at least 18 years who were admitted to the hospital with a primary diagnosis listed above and underwent colon resection were included. Patients with non-elective admissions were excluded from the study.

Outcomes

The primary outcomes were the following factors associated with MIS utilization: geographic region of the hospital, rural vs. urban location, hospital teaching status, hospital bed size, expected primary payer, and the individual patient's age, race, and sex. The NIS combines the location of a hospital (urban vs. rural) with the hospital teaching status. A hospital is considered a teaching hospital if it has at least one Accreditation Council for Graduate Medical Education (ACGME) approved residency program. Rural hospitals are not divided into teaching and non-teaching hospitals because of the infrequency of ACGME residency programs in rural hospitals. The secondary outcomes were the length of hospital stay, in-hospital mortality, and cost of open and MIS colectomies. HCUP calculates the cost of inpatient care by multiplying the total charges by a hospital-level cost-to-charge ratio; this ratio is calculated by information supplied by Centers for Medicare & Medicaid Services (CMS.)

Statistical analysis

The national estimates were calculated by considering the sample design elements, including clusters, strata, and trend weights provided by NIS. Continuous variables were presented as weighted means with standard error (SE), while categorical variables were presented as weighted counts (N) and percentages. To assess distributional disparities among categorical variables and the two groups (Open Colectomy and MIS), the Rao-Scott modified chi-square test was applied. To investigate the influence of Open Colectomy and MIS on in-hospital mortality, a multivariate logistic regression analysis was conducted. Furthermore, to explore the association between Open Colectomy and MIS and two numerical outcome variables, length of stay and hospital total charges, multivariate linear regressions were performed. Both the multivariate logistic regression model and the multivariate linear regression model were adjusted for patient demographics, hospital bed size, hospital location/teaching status, and insurance type.

All statistical analyses were performed using the SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA). Statistical significance was defined using two-sided test with a p-value of <0.05.

Results

A total of 100,100 patients underwent elective colectomy for diverticular disease between 2016 and 2019 (Table 1). The overall rate of MIS utilization remained fairly constant (54.4 % in 2016, 52.3 % in 2017, 51.8 % in 2018, and 54.3 % in 2019; $p = 0.81$). Hospitals in the Midwest used MIS less than those in other geographic regions (Midwest 49.2 %, Northeast 53.7 %, South 54.8 %, and West 55.1 %; $p < 0.0001$). Rural hospitals used MIS less than urban hospitals (rural 39.2 %, urban non-teaching 55.1 %, and urban teaching 54 %, $p < 0.0001$), although the difference narrowed over time (Fig. 1). Hospital bed size was not associated with differences in MIS utilization (small, 54.3 %; medium, 54.3 %; and large, 52.1 %; $p = 0.064$). Patient sex was also not associated with differences in MIS use (male 53.8 %; female 52.8 %; $p = 0.15$). MIS utilization decreased as patient age increased (age < 51, 58.1 %; age 51–65, 53.7 %; age 66–80, 49.2 %; and age > 80, 41.8 %; $p < 0.0001$).

There were significant variations in MIS utilization based on the expected primary payer (Medicare, 48.3 %; Medicaid, 48.6 %; private insurance, 56.7 %; self-pay, 48.7 %; and no charge, 39.7 %; $p < 0.0001$). There was also a racial disparity in MIS utilization (White, 53.2 %; Black, 46.7 %; Hispanic, 57.8 %; Asian and Pacific Islander, 55.6 %; Native American, 41.1 %; and Other, 55.5 %; $p < 0.0001$ %; Fig. 2). Adjusting for age, gender, household income, hospital type, hospital bed size, hospital region and hospital teaching status, we found that compared to White patients, Black patients exhibited a 0.23 lower odds of receiving MIS colectomy and Hispanic patients were 1.12 times more likely to receive MIS colectomy. Furthermore, compared to patients using Medicare, those with private insurance were 1.13 times more likely to have MIS colectomy (Table 2). Stratification analysis was performed in which patients were grouped according to the expected primary payer (Table 3). In this analysis, significant differences remained in MIS utilization rates by race. Among patients who used Medicare, compared to White patients, Black patients had 0.25 times lower odds of undergoing MIS ($p = 0.0162$) and Hispanic patients were 1.39 times as likely to undergo MIS ($p = 0.00212$.) Among patients who used private insurance, Black patients had 0.21 times lower odds of undergoing MIS ($p = 0.0122$.)

MIS was found to decrease the length of stay compared with open surgery (mean 3.9 days versus 5.4 days, $p \leq 0.0001$), with similar in-hospital mortality (0.1 % versus 0.2 %, $p = 0.32$) and similar overall hospital costs ($72,369 versus $77,296, $p = 0.43$) (Table 4).

Discussion

MIS represents a significant advancement in the surgical management of diverticular disease, offering a more favorable patient experience and outcomes. Laparoscopic and robotic-assisted techniques have allowed patients to experience reduced postoperative complications while improving patient satisfaction and recovery [11]. Our study found that most elective colectomies for diverticular disease in the United States are performed using MIS approaches. Consistent with other studies [5,12], we found that MIS was associated with decreased length of stay and similar costs.

Although rural hospitals continue to use MIS less than urban

Table 1
Laparoscopic colectomy (MIS) utilization by hospital characteristics and individual variables.

	Open colectomy (N = 46,830)	Laparoscopic colectomy (N = 53,270)	Total (N = 100,100)	p-value
	Weighted N (%)	Weighted N (%)	Weighted N (%)	
AGE				<0.0001
<51	10,725 (41.9)	14,855 (58.1)	25,580 (25.6)	
51–65	20,075 (46.3)	23,315 (53.7)	43,390 (43.3)	
66–80	14,270 (50.8)	13,835 (49.2)	28,105 (28.1)	
>80	1760 (58.2)	1265 (41.8)	3025 (3.0)	
Race				<0.0001
White	37,710 (46.8)	42,865 (53.2)	80,575 (80.5)	
Black	2790 (53.3)	2445 (46.7)	5235 (5.2)	
Hispanic	3515 (42.1)	4825 (57.9)	8340 (8.3)	
Asian or Pacific Island	300 (44.4)	375 (55.6)	675 (0.7)	
Native American	165 (58.9)	115 (41.1)	280 (0.3)	
Other	895 (44.5)	1115 (55.5)	2010 (2.0)	
Gender				0.15
Male	19,870 (46.2)	23,135 (53.8)	43,005 (43.0)	
Female	26,940 (47.2)	30,115 (52.8)	57,055 (57.0)	
HOSPITAL REGION				<0.0001
Northeast	9315 (46.3)	10,790 (53.7)	20,105 (20.1)	
Midwest	12,780 (50.8)	12,380 (49.2)	25,160 (25.1)	
South	17,010 (45.2)	20,635 (54.8)	37,645 (37.6)	
West	7725 (44.9)	9465 (55.1)	17,190 (17.2)	
Hospital type				<0.0001
Rural	4200 (60.8)	2705 (39.2)	6905 (6.9)	
Urban non-teaching	9945 (44.9)	12,220 (55.1)	22,165 (22.1)	
Urban teaching	32,685 (46.0)	38,345 (54.0)	71,030 (71.0)	
Hospital bed size				0.064
Small	9345 (45.7)	11,100 (54.3)	20,445 (20.4)	
Medium	14,280 (45.8)	16,930 (54.2)	31,210 (31.2)	
Large	23,205 (47.9)	25,240 (52.1)	48,445 (48.4)	
Expected primary payer				<0.0001
Medicare	17,265 (51.7)	16,125 (48.3)	33,390 (33.4)	
Medicaid	3425 (51.4)	3240 (48.6)	6665 (6.7)	
Private insurance	24,445 (43.3)	32,045 (56.7)	56,490 (56.4)	
Self-pay	705 (51.3)	670 (48.7)	1375 (1.4)	
No charge	115 (60.5)	75 (39.5)	190 (0.2)	
Other	850 (43.9)	1085 (56.1)	1935 (1.9)	

hospitals, the gap narrowed over the course of this study. While there is no longer any difference in MIS utilization based on hospital bed size or teaching status, disparities concerning patient race remain. Being Hispanic or Asian was associated with the highest MIS utilization, rate, whereas being Native American or Black was associated with the lowest. Furthermore, patients with private health insurance had higher MIS utilization compared with those who did not.

Racial disparities may reflect a combination of historical, social, and institutional factors that affect healthcare dispersion. Additionally, race-related differences in healthcare are not new findings. An NIS study examining patients with diverticular disease from 2009 to 2013 found that race was associated with significant differences in the use of laparoscopy for diverticular disease [13], while Robinson et al. [14] found insurance to be a predictive factor for MIS in colorectal disease. Akram et al. [15] further found that Black patients were significantly more likely to undergo an open colectomy than White patients. People of color are more likely to face lower incomes and higher rates of poverty, thus affecting their access to healthcare in a timely or preventative manner [16]. In part, race and insurance coverage may have confounded socioeconomic disparities. In a study examining disparities in MIS utilization for rectal cancer, Turner et al. [17] found that racial disparities disappeared after adjusting for factors such as insurance status. However, in our study on diverticular disease, we found that racial disparities in MIS utilization persisted even after adjusting for insurance status. In a separate study evaluating oncological outcomes for rectal cancer [18], racial disparities were diminished at high volume centers. Similarly, Robinson et al. [14] found that race was not associated with any significant difference in MIS utilization for colon resections performed at high-volume hospitals. In a study examining patients with colorectal cancer in California from 1996 to 2006, Non-White patients were less likely to be cared for than White patients at high-volume hospitals despite being more likely to live closer to them [19]. This may partly explain the disparities observed in our study.

National differences may affect the overall utilization of MIS techniques, possibly based on a general approach to healthcare. In comparison to the rate of 53 % MIS utilization in the United States, a Swiss study found an overall rate of 86 % for elective colectomies for diverticular disease [20]. It should be noted that the Swiss healthcare system differs from its American counterpart. The Swiss healthcare system is a mix of private and public healthcare with federal regulations establishing protocols for certain procedures and insurance coverage. The United States has a more heterogenous system and population, which may be reflected in its less standardized approach to individualized patient care. It should also be noted that the Swiss study was a prospective observational study. Nevertheless, the difference in these two rates of use may indicate room for growth in MIS use in the United States.

This study had some limitations. Since it was a population-based database study, it is inherently subject to coding errors. However, one might speculate that coding errors could have affected the different groups equally. Additionally, this study was limited by the lack of granular data. Specific circumstances, such as patient and individual surgeon variables, were not considered. For higher-risk patients, a quicker operation may have been desirable in certain cases, for which an open operation would be ideal. Although not a direct corollary, we found that MIS utilization decreased as the patient's age increased. Other factors included patients with prior abdominal operations whose expected adhesions may have played a role in choosing open surgery. Additional factors to be considered would be advanced diverticular disease or sepsis, although this may not have played a major role in this study as it was limited to elective operations. Finally, there may have been limitations to MIS use based on the surgeon's skill, the steep MIS learning curve, and the setting of the operating room. Training, resources, and volume are necessary for surgeons to perform MIS effectively and safely, as suggested by the data. Studies have found that the learning curve for laparoscopic colectomy is approximately 50 cases [21], with the learning curve for laparoscopic left colectomy being particularly crucial in obese patients [22]. Data from this and previous studies should consider the learning curve of surgical training to evaluate the use of the MIS approach.

Ultimately, MIS utilization in various hospital systems improves the surgical treatment of diverticular disease. MIS is associated with decreased post-operative complications, opioid use, and decreased

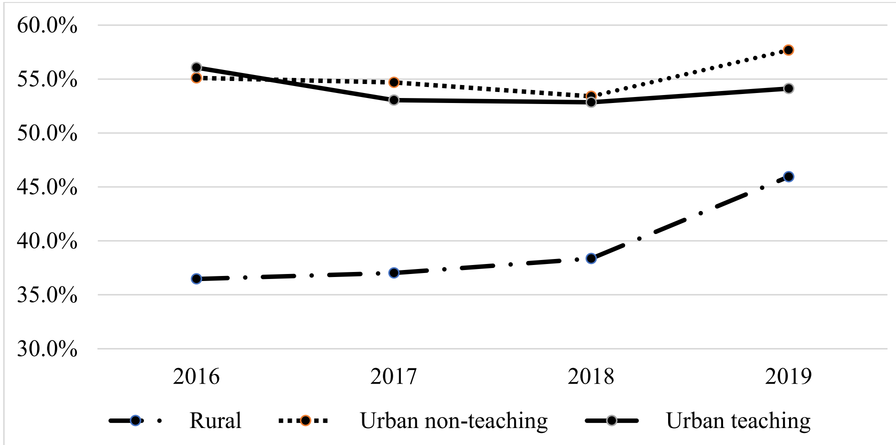

Fig. 1. MIS utilization by hospital type and year.

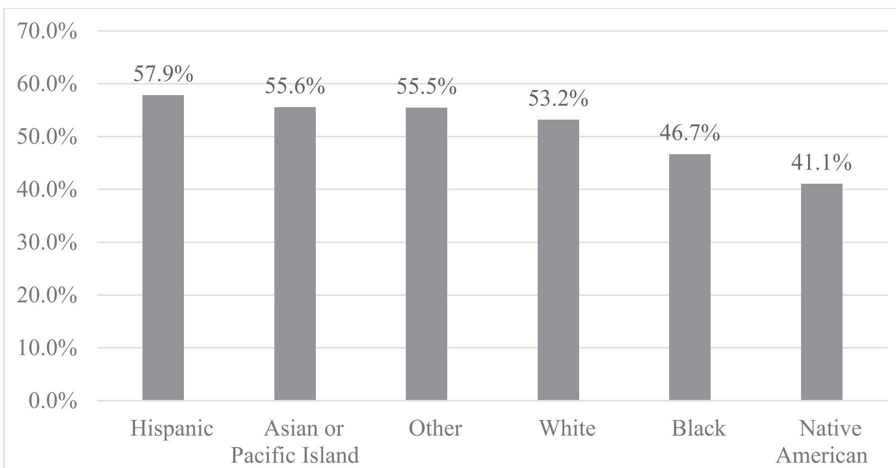

Fig. 2. MIS utilization by race.

Table 2
Laparoscopic colectomy (MIS) utilization by race and insurance status.

Outcomes	Open colectomy (N = 46,830)	Laparoscopic colectomy (N = 53,270)	Unadjusted results		Adjusted results	
	Weighted N (%)	Weighted N (%)	Odds Ratio (95 % CI)	p-value	Odds Ratio (95 % CI)	p-value
Race						
White	37,710 (46.8)	42,865 (53.2)	1	REF	1	REF
Black	2790 (53.3)	2445 (46.7)	0.77 (0.68,0.87)	0.00005	0.77 (0.68,0.88)	0.00012
Hispanic	3515 (42.1)	4825 (57.9)	1.21 (1.09,1.34)	0.00029	1.12 (1.01,1.25)	0.038
Asian or Pacific Island	300 (44.4)	375 (55.6)	1.10 (0.78,1.55)	0.58	0.98 (0.69,1.39)	0.92
Native American	165 (58.9)	115 (41.1)	0.61 (0.36,1.05)	0.072	0.63 (0.37,1.09)	0.098
Other	895 (44.5)	1115 (55.5)	1.10 (0.90,1.34)	0.36	1.00 (0.81,1.23)	0.98
Expected primary payer						
Medicare	17,265 (51.7)	16,125 (48.3)	1	REF	1	REF
Medicaid	3425 (51.4)	3240 (48.6)	1.01 (0.90,1.14)	0.83	1.08 (0.99,1.18)	0.088
Private insurance	24,445 (43.3)	32,045 (56.7)	1.40 (1.32,1.49)	<0.0001	1.13 (1.04,1.22)	0.0055
Self-pay	705 (51.3)	670 (48.7)	1.02 (0.80,1.30)	0.88	0.81 (0.63,1.05)	0.12
No charge	115 (60.5)	75 (39.5)	0.70 (0.36,1.34)	0.28	0.62 (0.32,1.21)	0.16
Other	850 (43.9)	1085 (56.1)	1.37 (1.11,1.68)	0.00302	1.12 (0.90,1.40)	0.29

length of hospital stay [23]. Additionally, the difference of cost between minimally invasive versus open elective sigmoid resections is not found to be significant [12,24]. If the costs are comparable but an MIS approach provides improved patient outcomes, then further consideration and research should continue to support increasing MIS utilization in the treatment diverticular disease.

Conclusions

MIS utilization in diverticular disease has the potential to improve patient care, post-operative outcomes, and be cost-effective. Most elective colectomies for diverticular disease in the United States are now performed using a minimally invasive approach. However, race and insurance coverage are barriers to MIS in this setting, with racial

Table 3
Laparoscopic colectomy (MIS) utilization by race, after stratification by primary payer.

Race	Medicare			Medicaid		
	Laparoscopic colectomy Weighted N (%)	Adjusted odds ratio (95 % CI)	p-value	Laparoscopic colectomy Weighted N (%)	Adjusted odds ratio (95 % CI)	p-value
White	13,410 (48.1)	1	REF	2215 (49.0)	1	REF
Black	725 (41.7)	0.75 (0.60,0.95)	0.016	325 (46.8)	0.86 (0.59,1.25)	0.42
Hispanic	1130 (57.5)	1.39 (1.13,1.72)	0.0021	515 (51.2)	0.98 (0.70,1.36)	0.89
Asian or Pacific Island	90 (48.6)	1.01 (0.53,1.92)	0.98	20 (40.0)	0.65 (0.18,2.36)	0.51

Race	Private insurance			Self-pay		
	Laparoscopic colectomy Weighted N (%)	Adjusted odds ratio (95 % CI)	p-value	Laparoscopic colectomy Weighted N (%)	Adjusted odds ratio (95 % CI)	p-value
White	25,915 (56.7)	1	REF	375 (46.6)	1	REF
Black	1280 (51.4)	0.79 (0.66,0.95)	0.012	45 (33.3)	0.73 (0.28,1.91)	0.52
Hispanic	2890 (59.5)	1.03 (0.89,1.18)	0.72	195 (60)	1.64 (0.80,3.34)	0.17
Asian or Pacific Island	245 (61.2)	1.01 (0.64,1.60)	0.96	15 (75)	2.69 (0.22,33.59)	0.44

Table 4
Secondary outcomes.

Outcomes	Open colectomy (N = 46,830)		Laparoscopic colectomy (N = 53,270)		Total (N = 100,100)		p-value
	Mean (SE)	Median (Q1, Q3)	Mean (SE)	Median (Q1, Q3)	Mean (SE)	Median (Q1, Q3)	
Length of Stay	5.4 (0.05)	4 (3, 6)	3.9 (0.03)	3 (2, 4)	4.6 (0.03)	4 (3, 5)	<0.0001
Total charges	77,296.0 (871.6)	61,161 (43,227, 90,416)	72,369.8 (726.5)	59,739 (42,227, 86,848)	74,675 (638.9)	60,390 (42,682, 88,708)	0.43
	Weighted N	%	Weighted N	%	Weighted N	%	p-value
In-hospital Mortality	110	0.2	60	0.1	170	0.2	0.32

disparities persisting even after adjusting for insurance status. Future research to understand these differences has the potential to continue to improve access of MIS operations.

Ethics approval

As a database study that utilizes the NIS, institutional review board review or exempt determination is not required. Research was done in accordance with the HCUP Data Use Agreement.

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CRediT authorship contribution statement

Arshad M. Bachelani: Conceptualization, Data curation, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Laura A. Holton:** Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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