ORIGINAL ARTICLE

Laparoscopic vs Open Colectomy

Outcomes Comparison Based on Large Nationwide Databases

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Hypothesis: Laparoscopic colectomy has significant advantages over open colectomy in the treatment of diverticular disease with respect to the length of hospital stay, routine hospital discharge, and postoperative morbidity and mortality.

Design: Retrospective secondary data analysis.

Patients and Setting: Patients with primary *International Classification of Diseases, Ninth Revision, Clinical Modification* procedure codes for laparoscopic (709 patients [3.8%]) and open sigmoid resection (17 735 patients [96.2%]) were selected from the 1998, 1999, and 2000 Nationwide Inpatient Samples. These databases represent 20% stratified probability samples of all US community hospital discharges. Sampling weights were used to allow generalization of the study findings to the overall US population. Multiple linear and logistic regression analyses were performed to assess the risk-adjusted association between the surgery type and patient outcomes.

Main Outcome Measures: Length of hospital stay, in-hospital complications, in-hospital mortality, and the rate of routine discharge.

Results: The patients had a mean age of 59.8 years; they were preponderantly white (89.1%) and female (54.0%). After adjusting for other covariates, laparoscopic sigmoidectomy was associated with a shorter mean hospital stay (laparoscopic sigmoidectomy vs open sigmoidectomy, 7.47 vs 9.37 days; $P<.001$), fewer gastrointestinal tract complications (odds ratio, 0.57; 95% confidence interval, 0.35-0.93; $P=.03$), a lower overall complication rate (odds ratio, 0.64; 95% confidence interval, 0.47-0.88; $P=.007$), and a higher routine hospital discharge rate (odds ratio, 2.21; 95% confidence interval, 1.51-3.21; $P<.001$).

Conclusion: Laparoscopic sigmoid resection in patients with diverticular disease has statistically and clinically significant advantages over open sigmoid resection with respect to the length of hospital stay, rate of routine hospital discharge, and postoperative in-hospital morbidity.

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DIVERTICULAR DISEASE is one of the most common disorders of the colon in elderly persons in Western countries. In North America, about one third of the people older than 45 years and two thirds of all persons older than 85 years have diverticular disease,[1,2] which leads to approximately 200 000 hospitalizations in the United States per year.[3] Consumption of a low-fiber diet has been identified as an important causative factor in developing diverticular disease.[1,4,5] For many decades, open colectomy has been the gold standard for the surgical treatment of acute or chronic diverticulits. The advent of endoscopic surgery and its success in laparoscopic cholecystectomy led to the idea of performing laparoscopic colectomy. In 1991, Fowler and White[6] performed one of the earliest laparoscopic sigmoid resections (LSRs). More than a decade later, however, the benefits of LSR are still controversial. Despite numerous retrospective medical record reviews and prospective observational studies comparing LSR with open sigmoid resection (OSR) in the treatment of symptomatic diverticular disease, a consensus concerning the relative advantages of each procedure has not yet been reached. Moreover, it is unknown whether LSR should be performed in the elderly population and in patients undergoing emergency surgery. The goal of this investigation was to compare the effectiveness of LSR with OSR in the overall population with diverticular disease, as well as in elderly and nonelectively admitted patients.

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METHODS

STUDY POPULATION

Patients with primary *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* procedure codes for LSR

Table 1. *International Classification of Diseases, Ninth Revision, Clinical Modification* Codes for Postoperative In-Hospital Complications

- Mechanical wound
  - Delayed wound healing, 998.83
  - Postoperative hematoma, 998.12
  - Postoperative seroma (noninfected), 998.13
  - Disruption of operative wound, 998.3
  - Persistent postoperative fistula, 998.6
- Infections
  - Postoperative infection, 998.5
  - Postoperative skin abscess, 998.59
  - Postoperative septic wound complications, 998.59
  - Postoperative skin infection, 998.59
  - Postoperative intra-abdominal abscess, 998.59
  - Postoperative subdiaphragmatic abscess, 998.59
  - Postoperative infected seroma, 998.51
- Urinary
  - Postoperative urinary retention, 997.5
  - Postoperative urinary tract infection, 997.5
- Pulmonary
  - Postoperative atelectasis, 997.3
  - Postoperative pneumonia, 997.3
  - Mendelson syndrome resulting from a procedure, 997.3
  - Postoperative acute respiratory insufficiency, 518.5
  - Postoperative acute pneumothorax, 512.1
  - Adult respiratory distress syndrome, 518.5
  - Postoperative pulmonary edema, 518.4
- Gastrointestinal tract
  - Postoperative small-bowel obstruction, 997.4
  - Postoperative ileus, 997.4
  - Postoperative ileus requiring nasogastric tube, 997.4
  - Postoperative nausea, 997.4
  - Postoperative vomiting, 997.4
  - Postoperative pancreatitis, 997.4
  - Complication of anastomosis of gastrointestinal tract, 997.4
- Cardiovascular
  - Postoperative deep venous thrombosis, 997.79
  - Postoperative pulmonary embolism, 415.11
  - Postoperative stroke, 997.02
  - Phlebitis or thrombophlebitis from procedure, 997.2
  - Cardiac arrest/insufficiency during or resulting from a procedure, 997.1
- Systemic
  - Postoperative shock (septic, hypovolemic), 998.0
  - Postoperative fever, 998.89
- Complications during the surgical procedure
  - Accidental puncture or laceration, complicating surgery, 998.2
  - Foreign body accidentally left during procedure, 998.4
  - Hemorrhage/bleeding complicating procedure, 998.11

(45.76 and 54.21) or OSR (45.76) were selected from the 1998, 1999, and 2000 Nationwide Inpatient Samples (NISs).[7-9] Patients having primary diagnosis codes other than diverticulosis (*ICD-9-CM* code 562.10) and diverticulitis (*ICD-9-CM* code 562.11) were excluded from our analysis. Furthermore, patients with any diagnosis code of cancer of the sigmoid colon were excluded (eg, malignant neoplasm of the sigmoid colon, *ICD-9-CM* code 153.3). The 1998, 1999, and 2000 NISs are part of the Healthcare Cost and Utilization Project and each contains information of approximately 7 million hospital discharges from a sample of more than 1000 hospitals in 22 (NIS 1998), 24 (NIS 1999), and 28 (NIS 2000) states in the United States. The American Hospital Association's definition of "community hospital" ("nonfederal, short-term, general, and other specialty hospitals, excluding hospital units of institutions"[7(p4)]) was used to select hospitals for the Healthcare Cost and Utilization Project database. The NIS was developed by the Agency for Healthcare Research and Quality as a partnership among industry and federal and state agencies to analyze trends in health care utilization, cost, quality, and outcomes. The NIS databases provide demographic data, hospital admission and discharge dates, discharge status, preoperative risk factors, postoperative complications, and vital status of patients discharged from US community hospitals during 1998, 1999, and 2000. The procedure and diagnostic codes are classified according to the *ICD-9-CM*. The NIS databases represent 20% stratified probability samples of all US community hospital discharges. Sampling strata were used for the creation of the NIS based on 5 hospital characteristics to ensure maximal representativeness of the US population—geographic region, ownership, location, teaching status, and bed size. Thus, the results of the present analysis can be extrapolated to the entire US patient population undergoing LSR or OSR for diverticular disease in the United States during 1998, 1999, and 2000.

MAIN OUTCOME MEASURES

Length of Hospital Stay

The length of hospital stay (measured in days) is defined as the difference between the date of admission and the date of discharge of the patient.

In-Hospital Complications

We examined all-cause, nonfatal in-hospital morbidity based on *ICD-9-CM* codes. Because the NIS databases contain inpatient data only and because patient data cannot be tracked longitudinally, complications occurring after hospital discharge were not included in our analysis. Complications were grouped into the following 8 categories: mechanical wound, infections, urinary, pulmonary, gastrointestinal tract, cardiovascular, systemic, and complications during the surgical procedure (**Table 1**).

In-Hospital Mortality

Vital status is a factor of the NIS databases. Because the NIS databases contain inpatient data only, deaths occurring after hospital discharge were not included in our analysis.

Rate of Routine Hospital Discharge

The NIS databases provide the following information about the patient's discharge status: (1) routine discharge, (2) short-term hospital stay, (3) skilled nursing facility, (4) intermediate care, (5) another type of facility, (6) home health care, (7) left against medical advice, and (8) death. Patients who left the hospital against medical advice (n=7) and patients who died during hospitalization (n=454) were excluded when analyzing this specific end point. The remaining patients were dichotomized into routine discharge (NIS variable DISPUniform 1) vs nonroutine discharge (NIS variable DISPUniform 2-6).

STRATIFIED ANALYSES OF END POINTS

We assessed the association between surgery type and risk-adjusted outcomes in stratified analyses for patients younger than 65 years (n=10952) and those 65 years or older (n=7492). Moreover, end points were assessed in the subset of elective patients (NIS variable ATYPE 3, elective) and patients undergoing nonelective surgery (NIS variable ATYPE 1, emergency; 2, urgent; 4, newborn; and 6, other). Stratified analyses were performed as age and admission type (elective vs nonelective) are likely to substantially influence the association between the surgical procedure and the outcomes.

COVARIATES

The primary predictor variable in the present investigation was the type of procedure (LSR [*ICD-9-CM* codes 45.76 and 54.21] or OSR [*ICD-9-CM* code 45.76]). Other covariates obtained from the NIS databases included age (in years), sex, race (white or other), household income (median household income of patient's ZIP code, 4 categories: 1=$1-$24999, 2=$25000-$34999, 3=$35000-$44999, and 4=$45000 and above), comorbidity (Charlson Index[10] modified by Deyo et al[11]), hospital volume (total number of overall discharges per year), geographic region (Northeast, Midwest, West, or South), teaching status of the hospital (rural nonteaching, urban nonteaching, or urban teaching), and admission type (elective or nonelective).

STATISTICAL ANALYSIS

All statistical analyses were performed using Stata Version 7.0 (Stata Corp, College Station, Tex) and GNU-R (Open Software Foundation Inc, Boston, Mass).[12] Since the NIS databases are stratified probability samples of US community hospitals, calculations were adjusted for survey sampling characteristics (probability weights, cluster sampling, and stratification). We used weights for a 20% sample of the total survey population, stratified for hospital region, ownership, teaching status, and bed size and having the hospital as the cluster unit. Differences between LSRs and OSRs with respect to baseline sociodemographic, comorbidity, and other predictor variables were tested using *t* tests, χ^2 tests, and analysis of variance.

Multiple linear regression models were used to examine the risk-adjusted association between the type of sigmoidectomy and length of hospital stay. Length of hospital stay showed a right-skewed distribution and was modeled using both raw length of hospital stay and log-transformed length of hospital stay. Similar results were found and, thus, only the findings using the raw length of hospital stay are presented as log-transformations have been problematic in previous investigations.[13,14] To assess the risk-adjusted influence of the type of procedure (LSR vs OSR) on the rate of routine hospital discharge, and the occurrence of overall and gastrointestinal tract complications, we used multiple logistic regression analyses. For other subsets of complications as well as for the assessment of mortality, the number of events were prohibitively small to support multivariable analysis.[15,16] All models were adjusted for the patient's comorbidity, age, sex, race, annual income, hospital teaching status, hospital location, admission type, and hospital volume. For stratified analyses by admission type (elective vs nonelective) and age (≥65 years vs <65 years), these covariates were dropped owing to multicolinearity.

To assess the influence of missing values for the covariates race and annual income on our results, we imputed missing values using expectation maximization algorithms.[17] Point estimates obtained by models with imputed variables were within a 10% range from the original models. Thus, models with imputed variables were deemed to be similar to models without imputing, and the results of the simplest models (without imputation) were reported.

RESULTS

These NIS databases contain information about 18444 patients undergoing LSR (n=709 patients [3.8%]) or OSR (n=17735 [96.2%]).

BASELINE CHARACTERISTICS

Patients had a mean age of 59.8 years; they were preponderantly white (89.1%) and female (54.0%). Eight thousand four hundred nine patients were operated on electively, whereas 8175 did not undergo elective surgery. Patients undergoing LSR were significantly younger (LSR, 53.0 years; OSR, 60.1 years), were more likely to be male (LSR, 52.4%; OSR, 45.7% male) with a higher income (mean income class: LSR, 3.30; OSR, 3.02), were less comorbid (mean Deyo index: LSR, 0.55; OSR, 1.73), and were more likely to be electively admitted (LSR, 62.9%; OSR, 44.9%). Compared with the OSR subset, patients undergoing LSR had fewer cases of hypertension, congestive heart failure, diabetes mellitus, coronary artery disease, and malignant neoplasms (**Table 2**).

LENGTH OF HOSPITAL STAY

Two thousand seven hundred nine patients had a hospital stay equal to or greater than 14 days (35 [4.9%] days after LSR; 2674 [15.1%] days after OSR; *P*<.001). The distribution of length of hospital stay for LSR and OSR is shown in the **Figure**. Two hundred sixty-one (57.5%) of 454 patients who died had a hospital stay shorter than 14 days, whereas 193 (42.5%) of 454 patients had a hospital stay of 14 days or longer. The unadjusted mean length of hospital stay was significantly shorter after LSR (5.7 days) than after OSR (9.32 days) (*P*<.001).

UNADJUSTED END POINTS

In univariate analyses, LSR was associated with a lower rate of in-hospital death (0.3%) than after OSR (2.5%) (*P*<.001) and a higher rate of routine hospital discharge (LSR vs OSR, 91.3% vs 70.9%; *P*<.001). The rate of mechanical wound complications (LSR vs OSR, 1.0% vs 2.0%; *P*=.04), pulmonary complications (LSR vs OSR, 2.5% vs 6.2%; *P*<.001), cardiovascular complications (LSR vs OSR, 0.7% vs 2.4%; *P*=.006), and overall complications (LSR vs OSR, 20.0% vs 29.1%; *P*<.001) were significantly lower in patients undergoing LSR (**Table 3**).

RISK-ADJUSTED END POINTS

After adjusting for other covariates (**Table 4**), LSR remained associated with a shorter mean hospital stay (LSR vs OSR, 7.47 vs 9.37 days; *P*<.001), a lower rate of gastrointestinal tract complications (odds ratio [OR], 0.57; 95% confidence interval [CI], 0.35-0.93; *P*=.03), a lower rate of overall complications (OR, 0.64; 95% CI, 0.47-0.88; *P*=.007), and a higher rate of routine hospital discharge (OR, 2.21; 95% CI, 1.51-3.21; *P*<.001).

END POINTS STRATIFIED BY ADMISSION TYPE

In stratified analyses (**Table 5**), the mean length of hospital stay remained statistically significantly shorter in the LSR subset of electively (*P*<.001) and nonelectively admitted patients (*P*<.001). The rate of routine hospital discharge was significantly higher for elective (*P*=.001) and nonelective patients (*P*=.03) undergoing LSR. The

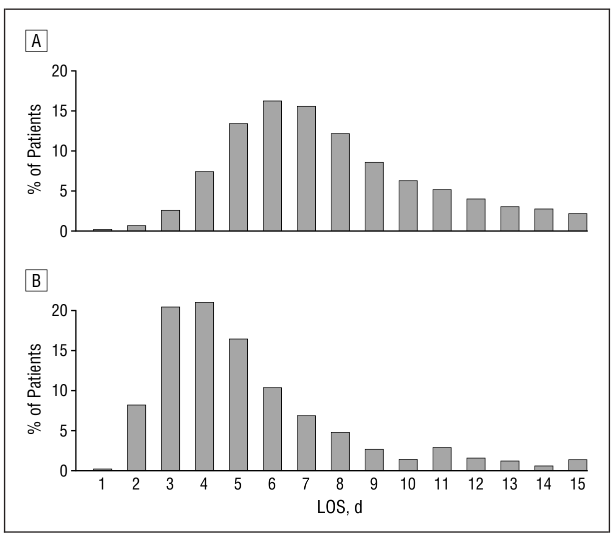
Table 2. Demographic Data of 18 444 Patients Undergoing Either Open Sigmoid Resection (OSR) or Laparoscopic Sigmoid Resection (LSR)*

Variable	Category	Patients Undergoing OSR (n = 17 735)	Patients Undergoing LSR (n = 709)	*P* Value
Age, y	Overall	60.1 (59.8-60.4)	53.0 (52.0-54.0)	<.001
	≥65	7350 (41.4)	142 (20)	<.001
	<65	10 385 (58.6)	567 (80)	
Race	White	12 310 (69.4)	477 (67.3)	
	Other	1482 (8.4)	94 (13.3)	.13
	Missing	3943 (22.2)	138 (19.5)	
Sex	Male	8111 (45.7)	372 (52.4)	
	Female	9621 (54.3)	337 (47.6)	.002
	Missing	3	0	
Median income index	NA	3.02 (2.97-3.07)	3.30 (3.20-3.40)	<.001
	Missing	483 (2.7)	22 (3.1)	
Deyo index†	NA	1.73 (1.66-1.81)	0.55 (0.41-0.69)	<.001
Hypertension	NA	4822 (27.2)	138 (19.5)	.004
Congestive heart failure	NA	856 (4.8)	9 (1.3)	<.001
Diabetes mellitus	NA	981 (5.5)	15 (2.1)	<.001
Coronary artery disease	NA	837 (4.7)	14 (2.0)	<.001
Peripheral vascular disease	NA	98 (0.6)	2 (0.3)	.36
Malignant neoplasms	NA	347 (2.0)	4 (0.6)	.01
Admission type	Elective	7963 (44.9)	446 (62.9)	
	Nonelective	8029 (45.3)	146 (20.6)	<.001
	Missing	1743 (9.8)	117 (16.5)	

Abbreviation: NA, not applicable.

*Data are given as the number (percentage) of patients. The initial parenthetical entry for the following variables is the 95% confidence interval of the mean for age, median income index, and Charlson Index[10] as modified by Deyo et al.[11] Because of rounding not all percentages total 100.

†The Charlson Index[10] as modified by Deyo et al[11] is the comorbidity summary index.



Frequency distribution of length of hospital stay (LOS) for patients undergoing (A) open sigmoid resection (OSR) and (B) laparoscopic sigmoid resection (LSR). The risk-adjusted length of hospital stay was significantly shorter after undergoing LSR compared with OSR (LSR vs OSR, 7.47 vs 9.37 days; *P*<.001).

overall complication rate was significantly lower in the subset of electively operated on patients undergoing LSR (OR, 0.53; 95% CI, 0.37-0.77; *P*=.001), whereas no significant difference between LSR and OSR was found for nonelective patients (OR, 0.87; 95% CI, 0.53-1.44; *P*=.59). Similarly, the advantage of LSR on gastrointestinal tract complications in elective patients (OR, 0.45; 95% CI, 0.25-0.80; *P*=.007) was lost in patients undergoing nonelective surgery (OR, *P*=.84).

END POINTS STRATIFIED BY AGE

In stratified analyses (**Table 6**), mean length of hospital stay remained statistically significantly shorter in the LSR subset of patients younger than 65 years (*P*<.001) and those 65 years or older (*P*<.001). Similarly, the rate of routine hospital discharge was statistically significantly higher for patients undergoing LSR who were younger than 65 years (OR, 2.30; 95% CI, 1.40-3.77; *P*=.001) than for those 65 years or older (OR, 2.18; 95% CI, 1.12-4.24; *P*=.02). The overall complication rate was significantly lower in the LSR subset of patients younger than 65 years (OR, 0.61; 95% CI, 0.43-0.87; *P*=.006) while no statistically significant difference between those undergoing LSR or OSR was found for elderly patients (OR, 0.74; 95% CI, 0.42-1.31; *P*=.29). No statistically significant advantage of LSR on gastrointestinal tract complications was observed either in younger patients (OR, 0.60; 95% CI, 0.35-1.04; *P*=.07) or in elderly patients (OR, 0.58; 95% CI, 0.22-1.49; *P*=.26).

COMMENT

To our knowledge, this is the first analysis comparing length of hospital stay, postoperative in-hospital morbidity and mortality, and the rate of routine hospital discharge in patients undergoing LSR and OSR based on combined NIS databases. In our investigation patients undergoing LSR had a significantly shorter risk-adjusted mean length of hospital stay (LSR vs OSR, 7.47 vs 9.37 days; *P*<.001) and a higher rate of routine hospital discharge (OR, 2.21; 95% CI, 1.51-3.21; *P*<.001) compared with patients undergoing OSR. After adjusting for other covariates, patients un-

Table 3. In-Hospital Complications, In-Hospital Death, and the Rate of Routine Hospital Discharge in Univariate Analyses*

Variable	Patients Undergoing OSR (n = 17 735)	Patients Undergoing LSR (n = 709)	*P* Value
In-hospital complications			
Mechanical wound	358 (2.0)	7 (1.0)	.04
Infections	647 (3.6)	19 (2.7)	.14
Urinary	196 (1.1)	11 (1.6)	.21
Pulmonary	1095 (6.2)	18 (2.5)	<.001
Gastrointestinal tract	1685 (9.5)	54 (7.6)	.14
Cardiovascular	422 (2.4)	5 (0.7)	.006
Systemic	420 (2.4)	17 (2.4)	.99
Complications during surgical procedure	330 (1.9)	11 (1.6)	.56
Overall	**5153** (29.1)	**142** (20.0)	<.001
Death	452 (2.5)	2 (0.3)	<.001
Routine hospital discharge of patient	12 570 (70.9)	647 (91.3)	<.001

Abbreviations: LSR, laparoscopic sigmoid resection; OSR, open sigmoid resection.
*Data are given as the number (percentage) of patients.

dergoing LSR had statistically significantly fewer gastrointestinal tract complications (OR, 0.57; 95% CI, 0.35-0.93; $P = .03$) and overall complications (OR, 0.64; 95% CI, 0.47-0.88; $P = .007$).

Laparoscopic cholecystectomy has been proven advantageous over open cholecystectomy with respect to length of hospitalization.[18,19] Whether LSR has similar benefits for patients undergoing colectomy for diverticular disease is less clear. A Consensus Development Conference including 16 international experts for treatment and diagnosis of diverticular disease recently concluded that laparoscopic surgery is probably better than open surgery for length of hospital stay.[3] Most matched-control[20-23] and prospective cohort[24] studies found LSR advantageous over OSR with respect to length of hospital stay. Other investigations comparing OSR and LSR procedures for different abdominal diseases confirmed this trend.[25-27] One large US multicenter clinical trial reported a statistically significant but clinically modest (5.6 vs 6.4 days) advantage of laparoscopic surgery for patients with colorectal cancer.[28] Another randomized controlled study from Germany reported a 1.5-day decrease in length of hospital stay after LSR (10.1 vs 11.6 days).[29] The variability of the published results regarding the length of hospital stay is considerable and may be due to a variety of factors. The current literature describes that the difference may be affected by hospital factors[30,31] or social habits[32] rather than reflecting differences caused by the operative technique itself. Moreover, further discrepancies may arise from diverse health care policies in different countries or different regions within a country. For instance, while Kohler et al[21] from Germany reported a length of hospital stay of 7.9 days for patients undergoing LSR and 14.3 days for patients undergoing OSR, Senagore et al[24] in Ohio found the the length of hospital stay was 3.1 days for patients undergoing LSR vs 6.8 days for patients undergoing OSR, and Faynsod et al[20] in California found that the length of hospital stay was 4.8 days for patients undergoing LSR and 7.8 days for patients undergoing OSR. The shorter length of stay in patients undergoing laparoscopic surgery can be explained by decreased postoperative pain,[28,29,33] less fatigue,[29] and faster recovery of intestinal peristalsis.[20,26,33] In the present investigation, the risk-adjusted mean length of hospital stay was 1.9 days shorter for patients undergoing LSR than for patients undergoing OSR. This undoubtedly represents an important advantage of laparoscopic surgery, both from a clinical and economic perspective.

Table 4. Risk-Adjusted Length of Hospital Stay, In-Hospital Complications, and the Rate of Routine Hospital Discharge

Variable	Risk-Adjusted Value (95% CI)	*P* Value
Procedure		
LSR	7.47 (7.36-7.58)*	<.001
OSR	9.37 (9.27-9.47)*	
In-hospital complications		
Gastrointestinal tract	0.57 (0.35-0.93)†	.03
Overall	0.64 (0.47-0.88)†	.007
Routine hospital discharge of patient	2.21 (1.51-3.21)†	<.001

Abbreviations: CI, confidence interval; LSR, laparoscopic sigmoid resection; OSR, open sigmoid resection.
*Data are given as the mean length of hospital stay in days. Risk-adjustment has been made for age, sex, race, annual household income, comorbidity, hospital volume, hospital location, admission type, and hospital teaching status.
†Data are given as the odds ratio for LSR vs OSR. Risk-adjustment has been made for age, sex, race, annual household income, comorbidity, hospital volume, hospital location, admission type, and hospital teaching status.

The question whether LSR reduces postoperative morbidity in patient with diverticular disease has been a matter of great debate. Some matched-control studies report similar occurrence in overall postoperative morbidity for LSR and OSR,[20,25] while others found statistically significant differences.[21,24,34] The reported overall complication rates after LSR for diverticular disease ranges from 8.2% to 28%.[20,21,24,35-41] The overall complication rate in the present study was 20.0% after LSR and 29.1% after OSR, and the risk-adjusted OR was significantly lower for LSR (OR, 0.64; 95% CI, 0.47-0.88; $P = .007$). Most overall complication rates in previous studies are lower compared with our results, potentially because of the performance of the procedures by well-trained surgeons in highly specialized centers. In our investigation, however, patients were drawn from all types of community hospitals, including teaching, nonteaching, urban, and

Table 5. Risk-Adjusted End Points Stratified by Admission Type

Variable	Admission Type	Risk-Adjusted Value (95% CI)	*P* Value
Length of hospital stay	Elective	LSR: 5.03 (4.97-5.08)* OSR: 7.19 (7.13-7.26)*	<.001
	Nonelective	LSR: 9.97 (9.92-10.02)* OSR: 11.60 (11.52-11.67)*	<.001
In-hospital complications			
Gastrointestinal tract	Elective	0.45 (0.25-0.80)†	.007
	Nonelective	0.92 (0.44-1.91)†	.84
Overall	Elective	0.53 (0.37-0.77)†	.001
	Nonelective	0.87 (0.53-1.44)†	.59
Routine hospital discharge of patient	Elective	2.96 (1.53-5.73)†	.001
	Nonelective	1.70 (1.04-2.77)†	.03

Abbreviations: CI, confidence interval; LSR, laparoscopic sigmoid resection; OSR, open sigmoid resection.
*Data are given as the mean length of hospital stay in days. Risk-adjustment has been made for age, sex, race, annual household income, comorbidity, hospital volume, hospital location, and hospital teaching status. The covariate admission type was dropped because of multicolinearity.
†Data are given as the odds ratio for LSR vs OSR. Risk-adjustment has been made for age, sex, race, annual household income, comorbidity, hospital volume, hospital location, and hospital teaching status. The covariate admission type was dropped because of multicolinearity.

Table 6. Risk-Adjusted End Points Stratified by Age

Variable	Age, y	Risk-Adjusted Value (95% CI)	*P* Value
Length of hospital stay	<65	LSR: 6.97 (6.84-7.09)* OSR: 8.77 (8.66-8.87)*	<.001
	≥65	LSR: 8.18 (8.06-8.30)* OSR: 10.22 (10.10-10.34)*	<.001
In-hospital complications			
Gastrointestinal tract	<65	0.60 (0.35-1.04)†	.07
	≥65	0.58 (0.22-1.49)†	.26
Overall	<65	0.61 (0.43-0.87)†	.006
	≥65	0.74 (0.42-1.31)†	.29
Routine hospital discharge of patient	<65	2.30 (1.40-3.77)†	.001
	≥65	2.18 (1.12-4.24)†	.02

Abbreviations: CI, confidence interval; LSR, laparoscopic sigmoid resection; OSR, open sigmoid resection.
*Data are given as the mean length of hospital stay in days. Risk-adjustment has been made for age, sex, race, annual household income, comorbidity, hospital volume, hospital location, and hospital teaching status. The covariate age was dropped because of multicolinearity.
†Data are given as the odds ratio for LSR vs OSR. Risk-adjustment has been made for age, sex, race, annual household income, comorbidity, hospital volume, hospital location, and hospital teaching status. The covariate age was dropped because of multicolinearity.

rural hospitals. Some studies comparing LSR with OSR for diverticular disease found significantly fewer postoperative wound infections,[24] pulmonary complications,[24] urinary tract infections,[21] and ileus[24] after LSR. We found a significantly lower risk-adjusted rate of postoperative gastrointestinal tract complications (OR, 0.57; 95% CI, 0.35-0.93; *P*=.03) in patients undergoing LSR.

Most studies report no mortality after LSR or OSR.[21,34,35,39,40] A German-Austrian prospective multicenter study on 500 consecutive cases of laparoscopic colorectal surgery reported an overall mortality of 1.8%.[42] This percentage compares with a mortality rate of 0.3% in patients undergoing LSR and 2.5% in patients undergoing OSR in our investigation. In univariate analysis we found a significantly lower percentage of death in patients undergoing LSR compared with patients undergoing OSR. Adjusting for other covariates was, however, impossible as the number of events in the subset of LSR was too low to support multivariable analyses.[15,16]

In the present investigation risk-adjusted routine hospital discharge was significantly higher in patients undergoing LSR vs those undergoing OSR (OR, 2.21; 95% CI, 1.51, 3.21; *P*<.001). Patients undergoing LSR were 2.2 times more likely to be discharged routinely from the hospital compared with patients undergoing OSR. Similarly, other studies found statistically significant advantages of LSR over OSR when comparing inpatient rehabilitation, maintaining independent status at admission, and return to partial and full activity.[25,26,34,43] The significantly higher percentage of routine hospital discharge is one of the most important findings of the present study. The quality of life and economic implications of loss of independence cannot be quantified through the present investigation. It can, however, be assumed that preoperatively independent patients who are forced to live in a nursing home after sigmoid resection are severely challenged, both from a quality-of-life and economic perspective.

It has been previously shown that laparoscopic colectomy is safe and cost-effective in patients undergoing elective surgery.[24,34] The question of whether a laparoscopic procedure has advantages over laparotomy in emergency situations remains an enigma. Most recent reports that compare LSR with OSR included elective patients only or did not provide stratified analyses of elective vs nonelective patients. To our knowledge, there is no well-designed investigation that compared end points of LSR and OSR in patients undergoing emergency surgery for diverticular disease. We found significant advantages of LSR in electively and nonelectively admitted patients for length of hospital stay and routine hospital discharge. Gastrointestinal tract and overall complications were significantly fewer in elective patients. This advantage of LSR was lost in nonelective patients.

The safety and feasibility of laparoscopic colectomy has been proven in patients in the fifth and sixth decades of life.[35,38,44] It is, however, a matter of great debate whether laparoscopic surgery should be performed in elderly patients. Most studies did not stratify the findings by age as their patient numbers were too small for subset analyses. Tuech et al[34] compared elective laparoscopic with open colectomies for sigmoid diverticulitis in patients older than 75 years. The authors found that laparoscopic surgery had significant advantages with respect to length of hospital stay, postoperative morbidity, and inpatient rehabilitation. Other studies of elderly patients with preponderantly malignant disease found similar benefits of laparoscopic surgery.[26,43] In our study, mean length of hospital stay was significantly shorter and the rate of routine hospital discharge was significantly higher for patients undergoing LSR, regardless of age. The overall complication rate was significantly lower in the subset of younger patients undergoing LSR ($P = .006$). The lower risk associated with LSR was not present in elderly patients ($P = .29$).

We would like to acknowledge the limitations of our study. First and most importantly, this is a large observational study and not a randomized clinical trial, and thus, patients undergoing LSR differed with respect to sociodemographics and comorbidities from patients undergoing OSR. However, even after risk-adjusting for patient and hospital level characteristics in multivariable analyses, LSR remained clearly advantageous over OSR for most outcomes under investigation.

Second, as our investigation is based on combined large administrative databases, it is possible that some procedures, diagnoses, and end points are miscoded. It can be assumed, however, that length of hospital stay, hospital discharge status, and vital status were adequately reported as these end points are not subject to subjective evaluation. Comparative analyses of the NIS databases with other databases concluded that the NIS databases perform very well and that NIS estimates such as in-hospital mortality and length of hospital stay are accurate and precise for both large groups ranging from the population of the United States, and small subsets with specific conditions.[45,46] Moreover, miscoding is likely to occur similarly in both LSR and OSR subsets. The problem of miscoding can be assumed to be less pertinent while comparing the 2 groups.

Third, the NIS databases do not allow for identifying patients who were converted from LSR to OSR. Analogous to the intention-to-treat principle in randomized clinical trials, patients undergoing a conversion should be analyzed in the pool of laparoscopic procedures, since the laparoscopic approach was initially chosen. In the present investigation, we were unable to use the intention-to-treat principle, as conversions from LSR to OSR were coded as an OSR. This may have biased our results toward performance of LSR. It has been reported that the conversion rates are considerably higher in patients undergoing emergency surgery[22,47] and in elderly patients.[48] In the present investigation, LSR had advantages when comparing length of hospital stay and routine hospital discharge regardless of admission status and age.

Fourth, the NIS databases allow the assessment of in-hospital morbidity and mortality only. Complications and death that occurred after hospital discharge were not captured in the NIS databases. Because patients after undergoing LSR leave the hospital significantly earlier than patients undergoing OSR, it could be hypothesized that the rate of complications and death after LSR captured in the NIS databases is falsely low when compared with the rate of complications and death after OSR. We were unable to adjust for the possible distortion of findings in complication and mortality rate introduced owing to the difference in length of hospital stay between patients undergoing LSR and those undergoing OSR.

Despite the aforementioned drawbacks inherent to secondary data analyses, the present investigation has numerous strengths. To our knowledge, the sample size is larger than in any previous publications thereby enabling us to reach conclusions with great confidence. Equally important, the findings of our analyses are based on real-world data, as the NIS databases are representative of the entire US population and show the effectiveness of LSR and OSR. This is opposed to randomized clinical trials that are subject to selection bias and assess the therapies' efficacy.[49]

CONCLUSIONS

We have shown that LSR has significant advantages over OSR with respect to length of hospital stay, rate of routine hospital discharge, and postoperative in-hospital morbidity. The advantage of LSR remains clinically and statistically significant in elderly and nonelectively admitted patients for length of hospital stay and routine hospital discharge. To our knowledge, this is the first investigation comparing end points after LSR and OSR based on a representative US nationwide database. Our findings may have important health care implications, not only resulting in clinical patient benefit but also in lowering hospital costs. Exponentially increasing health care costs have stimulated a massive health care reform effort seeking cost containment. It is imperative that health care professionals make fiscally prudent decisions, as the present environment necessitates a critical appraisal of apparently equi-efficacious therapeutic modalities. However, all aspects of LSR and OSR must be compared, including postoperative pain, patient's quality of life, missed days of work, procedural costs, total costs, and long-term complications. The present investigation based on representative US nationwide patient samples is only the first step in assessing all of these aspects. Further analyses to evaluate the aforementioned end points are required to define whether LSR should be considered the treatment of choice in patients with diverticular disease.

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REFERENCES

1. Aldoori WH, Giovannucci EL, Rockett HR, Sampson L, Rimm EB, Willett WC. A prospective study of dietary fiber types and symptomatic diverticular disease in men. *J Nutr.* 1998;128:714-719.
2. Roberts PL, Veidenheimer MC. Diverticular disease of the colon. In: Bayless TM, ed. *Current Therapy in Gastroenterology and Liver Diseases.* Vol 3. Toronto, Ontario: Decker; 1990:416-419.
3. Kohler L, Sauerland S, Neugebauer E, for the Scientific Committee of the European Association for Endoscopic Surgery. Diagnosis and treatment of diverticular disease: results of a consensus development conference. *Surg Endosc.* 1999; 13:430-436.
4. Brodribb AJ, Humphreys DM. Diverticular disease: three studies, part 1: relation to other disorders and fibre intake. *BMJ.* 1976;1:424-425.
5. Munakata A, Nakaji S, Takami H, Nakajima H, Iwane S, Tuchida S. Epidemiological evaluation of colonic diverticulosis and dietary fiber in Japan. *Tohoku J Exp Med.* 1993;171:145-151.
6. Fowler DL, White SA. Laparoscopy-assisted sigmoid resection. *Surg Laparosc Endosc.* 1991;1:183-188.
7. *Healthcare Cost and Utilization Project Nationwide Inpatient Sample 2000.* Springfield, Va: National Technical Information Service; 2001. Also available at: http://www.ahrq.gov/data/hcup/nis.htm. Accessed August 6, 2003.
8. *Healthcare Cost and Utilization Project Nationwide Inpatient Sample 1999.* Springfield, Va: National Technical Information Service; 2000. Also available at: http://www.ahrq.gov/data/hcup/nis.htm. Accessed August 6, 2003.
9. *Healthcare Cost and Utilization Project Nationwide Inpatient Sample 1998.* Springfield, Va: National Technical Information Service; 1999. Also available at: http://www.ahrq.gov/data/hcup/nis.htm. Accessed August 6, 2003.
10. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis.* 1987;40:373-383.
11. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with *ICD-9-CM* administrative databases. *J Clin Epidemiol.* 1992;45:613-619.
12. Ross I, Gentleman R. A language for data analysis and graphics. *J Compt Graph Stat.* 1996;5:299-314.
13. Diehr P, Yanez D, Ash A, Hornbrook M, Lin DY. Methods for analyzing health care utilization and costs. *Annu Rev Public Health.* 1999;20:125-144.
14. Wooldridge JM. *Introductory Econometrics: A Modern Approach.* Boston, Mass: South-Western College Publishing; 2000.
15. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. *J Clin Epidemiol.* 1996;49:1373-1379.
16. Katz M. Setting up a multivariable analysis: subjects. In: *Multivariable Analysis: A Practical Guide for Clinicians.* Cambridge, England: Cambridge University Press; 1999:60-83.
17. Little R, Rubin JA. *Statistical Analysis with Missing Data.* New York, NY: John Wiley & Sons Inc; 1987:152-156.
18. Hendolin HI, Paakonen ME, Alhava EM, Tarvainen R, Kemppinen T, Lahtinen P. Laparoscopic or open cholecystectomy: a prospective randomised trial to compare postoperative pain, pulmonary function, and stress response. *Eur J Surg.* 2000;166:394-399.
19. Sanabria JR, Clavien PA, Cywes R, Strasberg SM. Laparoscopic versus open cholecystectomy: a matched study. *Can J Surg.* 1993;36:330-336.
20. Faynsod M, Stamos MJ, Arnell T, Borden C, Udani S, Vargas H. A case-control study of laparoscopic versus open sigmoid colectomy for diverticulitis. *Am Surg.* 2000;66:841-843.
21. Kohler L, Rixen D, Troidl H. Laparoscopic colorectal resection for diverticulitis. *Int J Colorectal Dis.* 1998;13:43-47.
22. Sher ME, Agachan F, Bortul M, Nogueras JJ, Weiss EG, Wexner SD. Laparoscopic surgery for diverticulitis. *Surg Endosc.* 1997;11:264-267.
23. Liberman MA, Phillips EH, Carroll BJ, Fallas M, Rosenthal R. Laparoscopic colectomy vs traditional colectomy for diverticulitis: outcome and costs. *Surg Endosc.* 1996;10:15-18.
24. Senagore AJ, Duepree HJ, Delaney CP, Dissanaike S, Brady KM, Fazio VW. Cost structure of laparoscopic and open sigmoid colectomy for diverticular disease: similarities and differences. *Dis Colon Rectum.* 2002;45:485-490.
25. Chen HH, Wexner SD, Weiss EG, et al. Laparoscopic colectomy for benign colorectal disease is associated with a significant reduction in disability as compared with laparotomy. *Surg Endosc.* 1998;12:1397-1400.
26. Stocchi L, Nelson H, Young-Fadok TM, Larson DR, Ilstrup DM. Safety and advantages of laparoscopic vs open colectomy in the elderly: matched-control study. *Dis Colon Rectum.* 2000;43:326-332.
27. Bruce CJ, Coller JA, Murray JJ, Schoetz DJ Jr, Roberts PL, Rusin LC. Laparoscopic resection for diverticular disease. *Dis Colon Rectum.* 1996;39(suppl):S1-S6.
28. Weeks JC, Nelson H, Gelber S, Sargent D, Schroeder G. Short-term quality-of-life outcomes following laparoscopic-assisted colectomy vs open colectomy for colon cancer: a randomized trial. *JAMA.* 2002;287:321-328.
29. Schwenk W, Bohm B, Muller JM. Postoperative pain and fatigue after laparoscopic or conventional colorectal resections: a prospective randomized trial. *Surg Endosc.* 1998;12:1131-1136.
30. Lord RV, Sloane DR. Early discharge after open appendicectomy. *Aust N Z J Surg.* 1996;66:361-365.
31. Ramesh S, Galland RB. Early discharge from hospital after open appendicectomy. *Br J Surg.* 1993;80:1192-1193.
32. Millat B, Fingerhut A, Gignoux M, Hay JM, for the French Associations for Surgical Research. Factors associated with early discharge after inguinal hernia repair in 500 consecutive unselected patients. *Br J Surg.* 1993;80:1158-1160.
33. Lauro A, Alonso Poza A, Cirocchi R, et al. Laparoscopic surgery for colon diverticulitis. *Minerva Chir.* 2002;57:1-5.
34. Tuech JJ, Pessaux P, Rouge C, Regenet N, Bergamaschi R, Arnaud JP. Laparoscopic vs open colectomy for sigmoid diverticulitis: a prospective comparative study in the elderly. *Surg Endosc.* 2000;14:1031-1033.
35. Trebuchet G, Lechaux D, Lecalve JL. Laparoscopic left colon resection for diverticular disease. *Surg Endosc.* 2002;16:18-21.
36. Vargas HD, Ramirez RT, Hoffman GC, et al. Defining the role of laparoscopic-assisted sigmoid colectomy for diverticulitis. *Dis Colon Rectum.* 2000;43:1726-1731.
37. Eijsbouts QA, Cuesta MA, de Brauw LM, Sietses C. Elective laparoscopic-assisted sigmoid resection for diverticular disease. *Surg Endosc.* 1997;11:750-753.
38. Siriser F. Laparoscopic-assisted colectomy for diverticular sigmoiditis: a single-surgeon prospective study of 65 patients. *Surg Endosc.* 1999;13:811-813.
39. Smadja C, Sbai Idrissi M, Tahrat M, et al. Elective laparoscopic sigmoid colectomy for diverticulitis: results of a prospective study. *Surg Endosc.* 1999;13:645-648.
40. Bouillot JL, Aouad K, Badawy A, Alamowitch B, Alexandre JH. Elective laparoscopic-assisted colectomy for diverticular disease: a prospective study in 50 patients. *Surg Endosc.* 1998;12:1393-1396.
41. Carbajo Caballero MA, Martin del Olmo JC, Blanco JI, de la Cuesta C, Atienza R. The laparoscopic approach in the treatment of diverticular colon disease. *JSLS.* April-June 1998;2:159-161.
42. Kockerling F, Schneider C, Reymond MA, et al, for the Laparoscopic Colorectal Surgery Study Group (LCSSG). Early results of a prospective multicenter study on 500 consecutive cases of laparoscopic colorectal surgery. *Surg Endosc.* 1998; 12:37-41.
43. Stewart BT, Stitz RW, Lumley JW. Laparoscopically assisted colorectal surgery in the elderly. *Br J Surg.* 1999;86:938-941.
44. Berthou JC, Charbonneau P. Elective laparoscopic management of sigmoid diverticulitis: results in a series of 110 patients. *Surg Endosc.* 1999;13:457-460.
45. Agency for Health Care Policy and Research. *Comparative Analysis of HCUP and NHDS Inpatient Discharge Data.* Technical Supplement 13, NIS Release 5. Rockville, Md: Agency for Health Care Policy and Research. Available at: http://www.ahcpr.gov/data/hcup/nhds/niscomp.htm. Accessed December 7, 2002.
46. Health Cost and Utilization Project. *1999 HCUP Nationwide Inpatient Sample (NIS) Comparison Report.* Available at: http://www.ahcpr.gov/data/hcup/nisdoc00/nis_comparison_report_1999.pdf. Accessed December 7, 2002.
47. Franklin ME Jr, Dorman JP, Jacobs M, Plasencia G. Is laparoscopic surgery applicable to complicated colonic diverticular disease? *Surg Endosc.* 1997;11: 1021-1025.
48. Tuech JJ, Pessaux P, Regenet N, et al. Laparoscopic colectomy for sigmoid diverticulitis: a prospective study in the elderly. *Hepatogastroenterology.* 2001; 48:1045-1047.
49. Brenneman FD, Wright JG, Kennedy ED, McLeod RS. Outcomes research in surgery. *World J Surg.* 1999;23:1220-1223.