Impact of Surgeon and Hospital Caseload on the Likelihood of Performing Laparoscopic vs Open Sigmoid Resection for Diverticular Disease

A Study Based on 55,949 Patients

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Hypothesis: High-volume surgeons and hospitals are more likely to perform laparoscopic procedures than open procedures for diverticular disease as compared with low-volume surgeons and hospitals.

Design: Real-world analysis.

Setting: United States community hospitals.

Patients: Patients with primary International Classification of Diseases, Ninth Revision diagnosis codes for diverticulosis or diverticulitis and International Classification of Diseases, Ninth Revision procedure codes for laparoscopic or open sigmoidectomy were selected from the 1992 to 2001 Nationwide Inpatient Samples commercially available US databases.

Main Outcome Measures: The outcome variable was the likelihood of performing laparoscopic vs open sigmoid resection. The primary predictor variable was the annual caseload of sigmoid resections per surgeon and hospital.

Results: The study population included 55,949 patients who were predominantly white (70.5%) with a mean (SD) age of 60.7 (14.7) years. Unadjusted and risk-adjusted odds ratios of performing laparoscopic sigmoidectomy were significantly higher for high-volume surgeons and high-volume hospitals. In fact, high-volume surgeons were 8.80 times more likely to perform a laparoscopic sigmoid resection compared with low-volume surgeons. Similarly, in high-volume hospitals, patients were 3.02 times more likely to undergo a laparoscopic sigmoid resection compared with patients who underwent surgery in low-volume hospitals. These clinically relevant differences remained statistically significant in subset analyses stratified by age (<65 vs ≥65 years) and time of surgery (elective vs nonelective).

Conclusions: The findings of the present investigation based on data from large US nationwide databases provide compelling evidence that high-volume surgeons and hospitals are significantly more likely to perform laparoscopic surgery for diverticular disease compared with low-volume surgeons and hospitals. Based on recent studies showing clear advantages of the laparoscopic technique over the open counterpart, our results should be considered by both patients and physicians.

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Laparoscopic colorectal surgery was introduced in clinical practice more than a decade ago.1,2 Technical feasibility and safety of this minimally invasive procedure are now established.3-8 Moreover, significant advantages over the open procedure have been shown in numerous studies. In fact, laparoscopic colorectal surgery is associated with a reduced in-hospital morbidity and incidence of early infectious wound complications and late incisional hernia formations in addition to the obviously improved cosmesis.24-27

The association between high volume for surgeons and hospitals and better surgical outcomes is well documented for many surgical procedures.28-31 The literature32-41 suggests that this also applies to colorectal surgery for both the open and laparoscopic techniques. We thus purposefully refrained from evaluating clinical outcomes in this study. However, it is unknown whether the likelihood of performing laparoscopic vs open colon resection depends on the caseload of the surgeon or hospital. Therefore, the objective of this large study was to investigate the relationship between surgeon and hosp-
tal caseload and performance of laparoscopic surgery for diverticular disease.

Our a priori hypothesis was that high-volume surgeons and hospitals are more likely to perform laparoscopic sigmoid resection in patients with diverticular disease compared with low-volume surgeons and hospitals.

**STUDY POPULATION AND DESCRIPTION OF DATABASES**

Patients with primary International Classification of Diseases, Ninth Revision® procedure codes for laparoscopic sigmoid resection (codes 45.76 and 54.21) or open sigmoid resection (code 45.76) were selected from the 1992 to 2001 Nationwide Inpatient Samples databases. Patients with primary diagnosis codes other than diverticulosis (code 562.10) and diverticulitis (code 562.11) were excluded from our analysis. Furthermore, patients with the diagnosis code of cancer of the sigmoid colon (code 153.3) were excluded.

The Nationwide Inpatient Samples databases are among the largest commercially available inpatient databases in the United States, containing information on several million hospital discharges from more than 1000 hospitals per year. The Nationwide Inpatient Samples databases approximate a 20% stratified probability sample representative of community hospitals in the United States. To ensure maximal representativeness of the US population, sampling strata were used for the creation of the Nationwide Inpatient Samples databases based on 5 hospital characteristics: geographic region, ownership, urban or rural location, teaching status, and bed size.

**OUTCOME AND COVARIATES**

The outcome variable for this study was the likelihood of performing laparoscopic vs open sigmoid resection. The primary predictor variables were surgeon and hospital volume. Surgeon volume was divided into 5 mutually exclusive groups: group 1, 1 to 3 procedures per year; group 2, 4 to 6 procedures per year; group 3, 7 to 10 procedures per year; group 4, 11 to 15 procedures per year; and group 5, more than 15 procedures per year. Similarly, hospital volume was divided into 5 mutually exclusive groups: group 1, 1 to 10 procedures per year; group 2, 11 to 20 procedures per year; group 3, 21 to 30 procedures per year; group 4, 31 to 40 procedures per year; and group 5, more than 40 procedures per year. The cutoffs for the categories were chosen based on clinically relevant surgeon and hospital volumes. Choosing 5 categories allowed us to show an incremental increase of performing laparoscopic surgery with increasing volume, an approach that is often used in the volume outcomes literature.43,44 We initially used surgeon and hospital volume as continuous variables, as this is clearly more reader friendly and easier to interpret.

Other covariates obtained from the Nationwide Inpatient Samples databases included age, sex, household income (median yearly income in patient's ZIP code divided into 3 categories: category 1, $1-$25,000; category 2, $25,001-$35,000; category 3, ≥$35,001), comorbidity (Charlson Comorbidity Index score45 modified by Deyo et al46), time of surgery (elective vs nonelective), US region of the hospital (Northeast, Midwest, South, West), and location and teaching status of the hospital (rural nonteaching, urban nonteaching, or urban teaching hospital).

**STUDY METHODS**

**RESULTS**

Our database contained information from about 55,949 patients who underwent laparoscopic or open sigmoid resection in the years 1992 to 2001. Two thousand two patients (3.6%) underwent laparoscopic sigmoid resection and 53,947 (96.4%) underwent open sigmoid resection. The percentages of laparoscopic sigmoid resections remained constant over time and ranged from 2.7% to 4.2% (1992, 2.7%; 1993, 3.9%; 1994, 3.6%; 1995, 3.7%; 1996, 3.4%; 1997, 3.6%; 1998, 3.7%; 1999, 3.7%; 2000, 4.2%; and 2001, 3.3%). The percentages of laparoscopic sigmoid resections performed increased steadily with volume for both hospitals and surgeons (Table 1). Patients’ baseline characteristics distributed by surgeon and hospital volume are shown in Table 1. The mean (SD) age of our overall study population was 60.7 (14.7) years, and 44.0% of our patients were aged 65 years or older. Patients were female in 55.1% of all of the cases and were predominantly white (70.5%).

All of the statistical analyses were performed using Stata statistical software version 8.0 (Stata Corp, College Station, Tex) and SAS statistical software version 8.02 (SAS Institute, Inc, Cary, NC).

In the first step, bivariate analyses were performed to assess the association between surgeon and hospital volume and the unadjusted likelihood of performing laparoscopic sigmoid resection. Then, multivariate logistic regression models were used to examine the risk-adjusted association between surgeon or hospital volume and the likelihood of performing laparoscopic sigmoid resection.

The surgeon volume models were controlled for hospital volume, but surgeon volume was not used as a confounder for models with hospital volume as a main effect to avoid exclusion of records without surgeon identifiers. All of the models were adjusted for the patient’s comorbidity, age, sex, income, and time of surgery (elective vs nonelective), the hospital’s location and teaching status, and the US region of the hospital.

Adjusted odds ratios (ORs), 95% confidence intervals, and P values were used to express the strength of association between surgeon and hospital volume and the likelihood of performing laparoscopic sigmoid resection. The ORs of performing laparoscopic surgery were calculated using the lowest-volume surgeon and hospital categories as reference.

The data collection in the Nationwide Inpatient Samples databases is very complete; the exception of surgeon volume (missing data for surgeon volume in 27,207 patients [48.6%]), no missing data were encountered at a percentage greater than 10%. To assess the impact of missing surgeon identifiers on our results, sensitivity analyses using imputation by best subset regression were conducted. This method has been well described in the literature.47-49 Estimates of missing surgeon volumes were based on other known characteristics such as the location of the hospital where the patient was treated (urban or rural), US region in which the hospital was located, teaching status of the hospital, hospital bed size, and year of operation.
Almost two thirds (62.3%) of the high-volume surgeons performed surgery in high-volume hospitals. Similarly, nearly half (43.2%) of the low-volume surgeons were employed in low-volume hospitals (Table 2).

In bivariate analyses, there was a statistically significant association between both high surgeon and high hospital caseloads and an increased likelihood of performing laparoscopic sigmoid resection (Table 3). Even after adjusting for other covariates in multivariate analyses, this association remained highly statistically significant (Table 4). In fact, high-volume surgeons were 8.80 times more likely to perform a laparoscopic sigmoid resection compared with low-volume surgeons. Similarly, in high-volume hospitals, patients were 3.02 times more likely...
to undergo a laparoscopic sigmoid resection compared with patients undergoing surgery in low-volume hospitals. These statistically significant and clinically relevant differences were confirmed in subset analyses stratified by age (<65 vs ≥65 years) and time of surgery (elective vs nonelective) (Table 5).

Sensitivity analyses performed for missing values of surgeon volume showed results similar to those presented in our study, with high-volume surgeons and hospitals performing significantly more laparoscopic surgery compared with low-volume surgeons and hospitals.

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<th>Table 3. Unadjusted Odds Ratio of Undergoing Laparoscopic Surgery by Surgeon and Hospital Volume</th>
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Abbreviations: CI, confidence interval; NA, not applicable; OR, odds ratio.

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*Risk adjustment was for age, sex, comorbidity (Charlson Comorbidity Index score modified by Deyo et al), location and teaching status of the hospital, US region of the hospital, time of surgery (elective vs nonelective), and household income.

ings provide compelling evidence that high-volume surgeons (OR=8.80; 95% confidence interval=6.25-12.40; P<.001) and hospitals (OR=3.02; 95% confidence interval=2.51-3.65; P<.001) are significantly more likely to perform laparoscopic surgery for diverticular disease compared with low-volume surgeons and hospitals. These large differences remained statistically significant in subset analyses stratified by age (<65 vs ≥65 years) and whether elective or nonelective surgery was performed.

The association between high volume for surgeons and hospitals and better outcomes is well established for a variety of different surgical procedures. Several studies have shown that both the experience of the operating surgeon and the annual caseload of the hospital affect clinical outcomes after open colorectal surgery. Various authors investigated the association between the experience in performing laparoscopic colectomy and outcomes. They found significant decreases in the duration of surgery, length of postoperative hospital stay, and rates of intraoperative and postoperative complications with increasing experience. Based on these findings, most investigators have emphasized the association between greater surgical experience and better outcomes for this technically challenging, minimally invasive approach even beyond the initial steep learning curve.

We recently demonstrated that patients with rectal cancer treated by high-volume surgeons are 5 times more likely to undergo sphincter-sparing procedures than those treated by low-volume surgeons. It is intuitive that sphincter-sparing procedures, which often represent a technical challenge, are more frequently performed by high-volume surgeons with extensive experience. Based on the findings of this previous investigation, we hypothesized that high-volume surgeons and hospitals are more likely to perform laparoscopic sigmoid resections compared with low-volume surgeons and hospitals, as the laparoscopic resection is often more demanding than the open approach for inexperienced surgeons.

The present investigation proves this a priori hypothesis to be true and clearly shows that high-volume surgeons and hospitals were significantly more likely to perform laparoscopic sigmoid resection compared with low-volume surgeons and hospitals.

The minimal access of laparoscopic colorectal surgery offers substantial patient benefits compared with the open counterpart. Our group recently demonstrated significant advantages of laparoscopic colectomy over open colectomy with respect to the length of the hospital stay, rate of routine hospital discharge, and postoperative inhospital morbidity by performing a study of more than 18 000 patients with diverticular disease. The acceptance of laparoscopic surgery in the field of colonic cancer has been hampered by the lack of prospective randomized trials with adequate follow-up periods providing equal oncological clearance and long-term course. In the meantime, however, several excellent studies have confirmed better short-term outcomes and provide compelling evidence that the laparoscopic intervention does not jeopardize survival and disease control of patients with colorectal cancer. Laparoscopy has con-

COMMENT

To our knowledge, this study is the first in the literature that evaluates the relationship between surgeon and hospital caseloads and the likelihood of performing laparoscopic sigmoid resection for diverticular disease. Our find-
Regionalization for technically challenging surgery to centers performing a required minimum number of annual cases has repeatedly been suggested.\textsuperscript{29,60-64} Based on the combination of significant short-term advantages of the laparoscopic technique, its predominant availability at high-volume hospitals, and better operative quality of surgeons and hospitals with high caseloads, our results support the value of regionalization for the operative treatment of diverticular disease.

A third limitation is the missing information on surgeon caseload. However, imputation of missing values using best-subset regression showed no relevant changes of our results, emphasizing the robustness of our findings. Moreover, the risk-adjusted ORs were not only statistically significant but also clinically relevant, exceeding 3 for the highest hospital volume and 8 for the highest surgeon volume compared with low-volume hospitals and surgeons, respectively. We thus believe that these large differences cannot be explained solely by residual confounding but are in fact real.

Fourth, only 3.6% of all of the patients underwent laparoscopic surgery in this study. Although this percentage is small, the corresponding number (n = 2002) is considerable; this allows us to perform sound statistical analyses and obtain results that are representative for the United States.

Second, in this investigation, conversions from laparoscopic to open sigmoidectomy were coded as open sigmoid resections, and the Nationwide Inpatient Samples databases do not allow for identifying patients who underwent a conversion from the laparoscopic procedure to the open procedure. Nonetheless, the type of operation the surgeon initially intended to do is of minor relevance to the patient. Conversely, the type of resection the surgeon finally performed is of great relevance to the patient.

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Fourth, only 3.6% of all of the patients underwent laparoscopic surgery in this study. Although this percentage is small, the corresponding number (n = 2002) is considerable; this allows us to perform sound statistical analyses and obtain results that are representative for the United States.

Finally, we purposefully refrained from evaluating clinical outcomes in this study, as it is already known that high-volume surgeons and hospitals perform better than low-volume surgeons and hospitals. Instead, we focused on the previously unknown relationship between volume and choice of laparoscopic vs open sigmoid resection.

Despite the mentioned limitations, the investigation has numerous strengths. The sample size is very large, which allowed us to evaluate risk-adjusted results in the subsets of patients younger than 65 years vs those aged 65 years and older and in the patients who underwent elective vs nonelective operations with sufficient statistical power. Equally important, our analyses are based on real-world data from nationally representative stratified samples; thus, selection bias is minimal and the findings of the investigation are generalizable to the entire US population.

### CONCLUSIONS

This study, based on large databases, provides compelling evidence that high-volume surgeons and hospitals are significantly more likely to perform laparoscopic sigmoid resections compared with low-volume surgeons and hospitals. Based on recent articles showing short-term ad-
vantages of laparoscopic colectomy as compared with open colectomy and the association between higher case-loads and better outcomes, our results should be considered by both patients and physicians. If a laparoscopic sigmoid resection is deemed desirable, then directing patients with diverticular disease to high-volume surgeons and hospitals may be justified.

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Author Contributions: Drs Weber and Guller contributed equally to this work. Study concept and design: Guller, Pietrobon, and Oertli. Acquisition of data: Weber and Pietrobon. Analysis and interpretation of data: Weber, Guller, and Jain. Drafting of the manuscript: Weber and Guller. Critical revision of the manuscript for important intellectual content: Guller, Jain, Pietrobon, and Oertli. Statistical analysis: Jain. Administrative, technical, and material support: Weber and Pietrobon. Study supervision: Guller and Oertli.

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REFERENCES

he growth of laparoscopic surgery has accelerated exponentially since the first such procedures were performed in the early 1980s. Although we have gained nearly 15 years of experience since the first published description of minimally invasive approaches to colon surgery in 1991, laparoscopic colectomy is still infrequently performed in the United States despite apparent advantages. This article, using a large administrative database, confirms this fact and sheds some intriguing light on the subject.

First, it is noteworthy that 28,742 surgeons performed only 55,949 sigmoid colectomies over the sample of this database. Although the database is only a sample of 20% of patients undergoing these procedures, this study reveals what a true low-volume surgeon is! A high-volume surgeon is defined as one performing more than 15 sigmoid colectomies per year. This group of surgeons is apparently quite small, accounting for only 0.8% of the patients, whereas the low-volume surgeons (1–3 sigmoid colectomies per year) cared for almost 64% of the patients. Even if we expand the definition of a high-volume surgeon to as few as 7 sigmoid colectomies per year, only 10% of all patients would have been cared for by a high-volume surgeon. More interesting and perhaps worrisome is that 56% of the patients cared for by the low-volume surgeons were operated on urgently or emergently whereas only 21% of the patients cared for by the high-volume surgeons were operated on urgently or emergently. How can we explain this disparity? Numerous possibilities exist, including referral patterns, practice patterns, on-call responsibilities, and experience level to name a few. The net result is that any attempt to "corral" patients into the hands of a few high-volume surgeons or even high-volume hospitals is unlikely to succeed. Further, given the learning curve well accepted for laparoscopic colectomy, this article provides real estimates of the potential saturation of this technology in our current health care environment.

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