Original Investigation

Effect of Minimally Invasive Surgery on the Risk for Surgical Site Infections
Results From the National Surgical Quality Improvement Program (NSQIP) Database

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IMPORTANCE Surgical site infection (SSI) represents the second most common cause of hospital-acquired infection and the most common type of infection in patients undergoing surgery. However, evidence is scarce regarding the effect of the surgical approach (open surgery vs minimally invasive surgery [MIS]) on the risk for SSIs.

OBJECTIVE To evaluate the role of the surgical approach on the risk for SSIs in a large contemporary cohort of patients undergoing surgery across different specialties.

DESIGN, SETTING, AND PARTICIPANTS The American College of Surgeons National Surgical Quality Improvement Program database is a national, prospective perioperative database specifically developed to assess quality of surgical care. We queried the database from January 1, 2005, through December 31, 2011, for patients undergoing appendectomy (n = 97780), colectomy (n = 118407), hysterectomy (n = 26639), or radical prostatectomy (n = 11183).

EXPOSURES Thirty-day SSIs.

MAIN OUTCOMES AND MEASURES We abstracted the data on 30-day SSIs and compared patients undergoing open procedures and MIS using propensity score matching. Logistic regression analyses of the matched cohorts tested the association between the surgical approach and risk for SSIs.

RESULTS The overall 30-day rates of SSIs were 5.4% for appendectomy, 12.1% for colectomy, 2.8% for hysterectomy, and 1.7% for prostatectomy. After propensity score matching, MIS was associated with lower rates of postoperative SSIs in patients undergoing MIS vs open procedures for appendectomy (3.8% vs 7.0%; P < .001), colectomy (9.3% vs 15.0%; P < .001), hysterectomy (1.8% vs 3.9%; P < .001), and radical prostatectomy (1.0% vs 2.4%; P < .001). In logistic regression analyses, MIS was associated with lower odds of SSIs in patients treated with appendectomy (odds ratio [OR], 0.52 [95% CI, 0.48-0.58]; P < .001), colectomy (OR, 0.58 [95% CI, 0.55-0.61]; P < .001), hysterectomy (OR, 0.44 [95% CI, 0.37-0.53]; P < .001), and radical prostatectomy (OR, 0.39 [95% CI, 0.25-0.61]; P < .001).

CONCLUSIONS AND RELEVANCE The proportion of patients developing SSIs within 30 days after surgery can be substantial and depends on the type of surgery. Minimally invasive surgery is significantly associated with reduced odds of SSIs. This advantage should be considered when assessing the overall benefits of minimally invasive techniques.

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According to the Centers for Disease Control and Prevention, surgical site infections (SSIs) represent the second most common cause of hospital-acquired infection and the most common type of infection in patients undergoing surgery. In addition, SSIs are associated with significant morbidity and mortality and higher rates of readmission after hospital discharge, resulting in substantially higher expenditures. For these reasons, SSIs represent a major health care problem at the national level. The Centers for Disease Control and Prevention Healthcare Quality Promotion recently gave high priority to the National Action Plan to Prevent Healthcare-Associated Infections, which includes a 5-year national prevention target of 25% reduction in admission and readmission for SSIs.

Beyond the adoption of preventive measures for the reduction of SSIs during the perioperative period, the surgical approach itself may affect the risk for SSIs. Although some studies have demonstrated a reduction of SSIs with minimally invasive surgery (MIS), others have reported that both approaches are equivalent in their risk. Regardless, most of these studies relied on institutional data or retrospective population-based data, which have inherent limitations. The scarcity of high-quality data addressing this question has prompted the Institute of Medicine to include the appraisal of MIS vs conventional open surgery with regard to SSIs as a national priority for funded comparative effectiveness research.

On the basis of these considerations, we sought to examine the effect of minimally invasive approaches on the risk for SSIs in patients undergoing 4 common surgical procedures (appendectomy, colectomy, hysterectomy, and radical prostatectomy) within data collected in the American College of Surgeons National Surgery Quality Improvement Program (NSQIP). The NSQIP database was specifically developed to assess the quality of surgical care and prospectively collects perioperative data on preoperative patient characteristics, intraoperative variables, and 30-day postoperative mortality and morbidity for patients undergoing major surgical procedures in the United States. Data from the NSQIP have been shown to detect complications more reliably than administrative databases or institutional series. We hypothesize that patients undergoing MIS for a range of surgical procedures would have lower rates of SSIs.

Methods

Population Source
The present study relied on the NSQIP database. The NSQIP is an initiative by the American College of Surgeons that allows for the collection of risk-adjusted data to facilitate the assessment of outcome measures after surgery. A trained surgical clinical reviewer prospectively collects the NSQIP data. Validated data from patients’ medical records allow quantification of 30-day, risk-adjusted surgical outcomes, including after discharge, when nearly 50% of complications occur. In 2011, the NSQIP included data from 315 participating sites and more than 442,149 cases.

Covariates

For all patients, age at surgery, race, smoking status, alcohol intake, body mass index, baseline comorbidities, American Society of Anesthesiology physical status, and type of surgery (open vs minimally invasive approaches) were abstracted. For patients undergoing colectomy and hysterectomy, a variable was created to distinguish patients undergoing surgery for malignant neoplasms (International Classification of Diseases, Ninth Revision [ICD-9] codes 153 and 154 for malignant neoplasms of the digestive system; ICD-9 codes 180, 182, 183, and 184 for malignant neoplasms of the uterus and female genital organs). For patients undergoing colectomy and appendectomy, a variable was created to distinguish emergency from elective cases. Finally, for patients undergoing appendectomy, a variable was created to distinguish perforated appendicitis (ICD-9 codes 540.0, and 540.1) from nonperforated cases.

End Points

The primary end points consisted of SSIs. We defined SSIs as superficial (only skin or subcutaneous tissue of the incision), deep (deep soft tissues), and organ space (any part of the anatomy other than the incision, which has been opened and manipulated during the operation), as provided by the NSQIP.

Statistical Analysis

Descriptive statistics of categorical variables focused on frequencies and proportions. Means, medians, and interquartile ranges were reported for continuously coded variables. The χ2 and independent-samples t tests were used to compare proportions and medians, respectively. Owing to inherent differences between patients undergoing MIS and open surgery, we adjusted data using 1-to-1 propensity score matching. This procedure minimizes potential selection bias by balancing covariates between the comparison cohorts. Propensity scores were
computed for each surgical procedure by modeling a logistic regression with the dependent variable as the odds of undergoing MIS and the independent variable of age, race, sex (only for appendectomy and colectomy), body mass index, American Society of Anesthesiologists score, smoking status, diagnosis of malignant neoplasm (only for colectomy and hysterectomy), perforated appendicitis (only for appendectomy), and emergent surgery (only for appendectomy and colectomy). Finally, we examined covariate balance between the matched groups. Subsequently, univariable logistic regression analyses of the matched cohorts tested the association between surgical approach and the risk for SSIs. All statistical tests were performed using a statistical package available in the public domain (R, version 3.0.2; http://www.r-project.org/), with a 2-sided significance level set at $P < .05$.

### Results

#### Baseline Characteristics

From January 1, 2005, through December 31, 2011, 254,009 patients underwent the following surgical procedures within the NSQIP database: appendectomy ($n = 97,780$), colectomy ($n = 118,407$), hysterectomy ($n = 26,639$), and radical prostatectomy ($n = 11,183$). Baseline characteristics of the patients included in the study before and after propensity score matching are depicted in eTables 2 through 5 in the Supplement. After propensity score matching, 36,880 patients undergoing appendectomy, 85,978 undergoing colectomy, 22,132 undergoing hysterectomy, and 5,738 undergoing radical prostatectomy remained. The mean standardized differences of patient characteristics between the 2 groups were less than 10%, indicating a high degree of similarity in the distribution of both populations. All subsequent analyses were based on the propensity-matched cohort.

#### Bivariate Analyses

Overall, 19,835 (5.4%), 10,417 (12.1%), 626 (2.8%), and 98 (1.7%) patients treated with appendectomy, colectomy, hysterectomy, and radical prostatectomy, respectively, experienced SSIs. Among patients treated with appendectomy, the rates of superficial, deep, and overall SSIs were significantly lower in patients undergoing MIS compared with patients undergoing open surgery (Table) ($P < .001$). Similarly, in patients treated with colectomy, the rates of superficial, deep, organ-space, and overall SSIs were significantly lower among those undergoing MIS compared with patients undergoing open surgery (Table) ($P < .001$). In patients treated with hysterectomy, the rates of superficial, deep, and overall SSIs were lower among those undergoing MIS compared with their counterparts undergoing open surgery (Table) ($P < .001$). Finally, in patients treated with radical prostatectomy, the rates of superficial and overall SSIs were lower among men undergoing MIS compared with their counterparts undergoing open surgery (Table) ($P < .001$).
Logistic Regression Analyses
In patients treated with appendectomy, MIS was associated with lower odds of overall SSIs compared with open surgery (odds ratio [OR], 0.52 [95% CI, 0.48-0.58]; P < .001) (Table). Similarly, patients treated with MIS had significantly lower odds of superficial and deep SSIs (P < .001).

In patients treated with colectomy, MIS was associated with lower odds of overall SSIs compared with open surgery (OR, 0.58 [95% CI, 0.55-0.61]; P < .001) (Table). This association held true even when superficial, deep, and organ-space SSIs were each considered as the end point (P < .001).

In patients treated with hysterectomy, MIS was associated with lower odds of SSIs compared with open surgery (OR, 0.44 [95% CI, 0.37-0.53]; P < .001) (Table). Similarly, patients treated with MIS had lower odds of superficial and deep SSIs (P < .001).

Finally, in patients treated with radical prostatectomy, MIS was associated with lower odds of SSIs compared with open surgery (OR, 0.39 [95% CI, 0.25-0.61]; P < .001) (Table). Similarly, patients treated with MIS had lower odds of superficial SSIs (OR, 0.44 [95% CI, 0.25-0.75]; P = .003).

Discussion
The results of our investigation indicate that the proportion of patients who develop SSIs within 30 days of surgery is substantial, varying from 1.7% to 12.1%, depending on the type of surgery. In addition, we demonstrate that the adoption of MIS approaches is associated with a significant reduction in the odds of overall postoperative SSIs for all the examined procedures. The consistency of these findings among individuals undergoing a variety of procedures provides compelling evidence regarding the benefits of MIS for reducing the risk for SSIs.

The prevention of SSIs represents a national priority, and targeted policies aimed at reducing the risk for SSIs have been advanced. Indeed, SSIs represent a common postoperative complication associated with physical discomfort and prolonged recovery time in the postoperative period and may affect a patient’s quality of life significantly. In addition, the occurrence of an SSI substantially increases the risks for readmission and postoperative mortality and has a bearing on the costs of health care. Although the adoption of preventive measures is essential, the type of surgical approach may be as important in reducing the risk for SSIs. In this context, previous retrospective studies attempting to address this issue have reported conflicting results. For example, Tuggle et al showed that in cases of complicated appendicitis, laparoscopic surgery had lower rates of superficial and deep wound infections. However, they reported that MIS was associated with increased risk for intra-abdominal abscess. Conversely, our results did not show an association between surgical approach and the risk for organ-space infections in patients undergoing appendectomy, even after adjusting for the occurrence of complicated appendicitis. In addition, our observations corroborate the findings of Varela et al, who analyzed the effect of MIS on the risk for SSIs in an administrative database, including individuals treated with 1 of 4 commonly performed gastrointestinal tract procedures. The authors showed that, in their large cohort of patients treated with appendectomy, cholecystectomy, antireflux surgery, or gastric bypass, MIS was associated with a lower risk for SSIs. On the other hand, Dobson et al failed to show a significant reduction in the rates of SSIs in patients undergoing colorectal surgery with a laparoscopic approach. However, they included a relatively small historic cohort of patients treated at a single institution and excluded individuals who experienced organ-space SSIs. In comparison, the strengths of our study consist of the large cohort, prospectively collected data, and inclusion of organ-space SSIs. In fact, in our study the proportion of patients experiencing an organ-space SSI was significantly lower among individuals undergoing minimally invasive colectomy. We can hypothesize that the inclusion of these patients would have resulted in a substantial advantage for laparoscopy in terms of SSIs in the previous study. Dobson et al demonstrated that, when an SSI occurred, patients treated with laparoscopy experienced less morbidity and incurred lower costs than their counterparts undergoing an open procedure. This finding is consistent with what was reported by Tollefson and colleagues, who showed that SSIs that developed after robot-assisted radical prostatectomy were less severe compared with those that developed in patients treated with the traditional open approach.

Together these findings support the proposed benefits of MIS in terms of smaller surgical incisions and elimination of mechanical retraction of the surgical site. Hypothetically, these factors may result in less systemic stress, improved immunologic response, and less local tissue trauma, leading to lower rates of SSIs for patients treated with MIS. Tollefson et al, in their study, such as other types of complications, therapeutic effectiveness, and costs, should be considered when comparing the pros and cons of MIS.

Our study has several strengths. Our observations were obtained using data from the NSQIP database. The NSQIP is a quality assurance program for major surgical procedures administered by the American College of Surgeons. The hallmark of this database is rigorous data collection, with detailed 30-day data on perioperative patient characteristics and postoperative outcomes collected prospectively and validated by trained surgical clinical reviewers in a reliable and comprehensive fashion. This process circumvents the potential pitfalls of studies relying on institutional databases or population-based cohorts. Further, the inclusion of a large cohort of contemporary patients treated with 4 different operations allowed us to assess the effect of the surgical technique on the risk for SSIs across different clinical scenarios. In particular, we used the method of propensity score matching to minimize the chance that our results might be attributable to treatment bias.

To our knowledge, this report represents the first time this benefit has been demonstrated within a single study across...
multiple surgical specialties. In this context, the variation of risk for SSIs across the different type of procedures, resulting in a substantial variability in the reduction of SSI rates among the different specialties, should be highlighted. As a consequence, the magnitude of the effect of MIS on the risk for SSIs is different according to the type of procedure, with patients treated with radical prostatectomy reaping the greatest benefits. On the other hand, additional measures could be necessary to achieve a satisfactory reduction in SSI rates for patients undergoing procedures at higher risk for postoperative infections, such as colectomy and appendectomy.

However, our study has some limitations. First, the NSQIP does not provide data on disease characteristics, and therefore we were not able to adjust our analyses for these variables. We tried to circumvent this limitation by adjusting our analyses for the diagnosis of neoplastic malignant disease. Second, the lack of hospital and payer characteristics prevented assessment of the effect of hospital volume or other socioeconomic factors such as insurance status on outcomes. In addition, we were not able to adjust our analyses for the surgical volume. Indeed, the number of procedures a surgeon or center performs might substantially affect the risk for postoperative complications. In our defense, this limitation applies to minimally invasive and open surgical approaches and consequently should not affect the overall validity of our findings. Moreover, although we may speculate that the decrease in the rate of SSIs observed in patients treated with MIS would result in lower costs, lack of data on this variable did not allow us to address this issue comprehensively. Finally, the voluntary participation in NSQIP requires resources, which may select for larger, high-volume institutions that are known to have lower rates of postoperative complications.

Conclusions

The risk for SSIs is not negligible among patients undergoing appendectomy, colectomy, hysterectomy, and radical prostatectomy. Patients undergoing MIS are at substantially lower risk for SSIs compared with their counterparts undergoing open surgery. These observations should be considered when assessing the comparative effectiveness of MIS vs open surgical approaches.
Is a Minimally Invasive Approach the Solution for Reducing Surgical Site Infections?

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During the past decade, performance of minimally invasive surgery (MIS) has rapidly disseminated into clinical practice for commonly performed procedures in the United States owing to lowering of the risk for complications, shortening of the length of stay, and improving convalescence compared with open surgery.\(^1\)\(^2\) Assessing the effect of MIS on the risk for surgical site infections (SSIs) is a salient question, because SSIs occur in at least 2% of all surgical procedures and are increasingly targeted under contemporary health care reform.\(^3\)

Using data from the National Surgical Quality Improvement Program, Gandaglia et al\(^4\) investigate the association between surgical approach (MIS vs open) and SSIs for the following 4 commonly performed procedures: appendectomy, colectomy, hysterectomy, and prostatectomy. In more than 250,000 patients, the authors demonstrate substantial variation in SSI rates (1.7%-12.1%) across procedures, but report that MIS for each procedure type was associated with lower odds of SSIs after propensity matching.\(^4\)

The authors present compelling data but, because of limitations in the data, their study cannot address other complications or costs, which is necessary to assess the comparative effectiveness of each individual procedure type robustly. Furthermore, differentiation between laparoscopic and robotic approaches is not possible, which in light of current controversies regarding the increased health care costs of implementing new technologies affects the clinical relevance of the reported findings.\(^2\)\(^5\)

Although SSIs represent a single component in defining surgical quality, contemporary comparative effectiveness research efforts have expanded to include patient-centered outcomes such as patient preferences, satisfaction, and quality of life in addition to the more traditionally measured outcomes such as mortality, complications, readmissions, and costs. Because future randomized studies are unlikely, clearly defining outcomes meaningful to patients, health care professionals, and key stakeholders is essential to determining whether an MIS is superior to open surgery or simply another tool selectively used at the discretion of the surgeon on an individual patient basis.

ARTICLE INFORMATION

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