Balancing the Risk of Postoperative Surgical Infections

A Multivariate Analysis of Factors Associated With Laparoscopic Appendectomy From the NSQIP Database

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Objective: To establish the relationship between operative approach (laparoscopic or open) and subsequent surgical infection (both incisional and organ space infection) postappendectomy, independent of potential confounding factors. **Background:** Although laparoscopic appendectomy has been associated with lower rates of incisional infections than an open approach, the relationship between laparoscopy and organ space infection (OSI) is not as clearly established. **Methods:** Cases of appendectomy were retrieved from the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database for 2005 to 2008. Patient factors, operative variables, and the primary outcomes of incisional infections and OSIs were recorded. Factors associated with surgical infections were identified using logistic regression models. These models were then used to calculate probabilities of OSI in clinical vignettes demonstrating varying levels of infectious risk. **Results:** A total of 39,950 appendectomy cases were included of which 30,575 (77%) were performed laparoscopically. On multivariate analysis, laparoscopy was associated with a lower risk of incisional infection [odds ratio (OR) 0.37, 95% confidence interval (CI) 0.32–0.43] but with an increased risk of OSI after adjustment for confounding factors (OR 1.44, 95% CI 1.21–1.73). For a low-risk patient, probability of OSI was calculated to be 0.3% and 0.4%, respectively, for open versus laparoscopic appendectomy, whereas for a high-risk patient, probabilities were estimated at 8.9% and 12.3%, respectively. **Conclusion:** Laparoscopy was associated with a decreased risk of incisional infection but with an increased risk of OSI. The degree of this increased risk varies depending on the clinical profile of a surgical patient. Recognition of these differences in risk may aid clinicians in the choice of operative approach for appendectomy.

Key Words: appendectomy, laparoscopic, organ space infection

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Appendicitis remains the most common general surgical emergency in developed countries, with an estimated 252,682 appendicitis-related hospitalizations in the United States in 1997.[1,2] Laparoscopic appendectomy has been widely adopted in the management of acute appendicitis because of its demonstrated advantages over open appendectomy in terms of shorter length of hospital stay, reduced superficial wound infection, and reduced postoperative ileus.[3,4] An area of concern is the finding that the laparoscopic approach was associated with a 2- to 3-fold increased risk of postoperative organ space (intraperitoneal) infection compared with the open approach in meta-analyses.[3–6] Organ space infection (OSI) postappendectomy occurs in approximately 1.6% to 3.0% of all cases; however, in patients with complicated (gangrenous or perforated) appendicitis, postoperative OSI rates of 7.0% to 15% have been reported.[3,6,7] This is a significant complication that typically requires a prolonged hospital stay or readmission for intravenous antibiotics and drainage of the collection.

This putative association between the laparoscopic approach and postoperative OSI has led some authors to advocate conversion to an open appendectomy in the context of complicated appendicitis to potentially reduce the risk of an OSI.[8] This association has been refuted by other studies, which have reported that laparoscopic appendectomy was not associated with an increased risk of OSI, even in the context of complicated (gangrenous or perforated) appendicitis (well-recognized risk factors for postoperative infection).[6,7] It is difficult to draw a definitive conclusion on the relationship between laparoscopy and OSI because the studies to date advocating its use involve small patient populations, whereas the total number of events (90 postappendectomy operative OSIs) in the meta-analyses is relatively small.[3] Furthermore, many of the studies examining surgical site infections postappendectomy have not controlled for potential confounding factors such as wound class, operative time, obesity, and smoking history. The aim of this study was to determine if a laparoscopic approach was associated with an increased risk of OSI in a large patient cohort, while controlling for well-known surgical risk factors.

METHODS

The American College of Surgeons National Surgical Quality Improvement Program (NSQIP) comprises a clinical database with systematic data collection conducted at hundreds of hospitals throughout the United States. Details of the NSQIP sampling strategy, data abstraction, parameters collected, and outcomes recorded have been reported previously.[9] In brief, the program collects information pertaining to patient demographics, preoperative medical history, clinical findings, and laboratory investigations. Postdischarge follow-up data are obtained both from chart review and a standardized phone interview with the patient by a certified nurse reviewer with the intention of capturing complications up to 30 days postoperatively.

The NSQIP database was queried for patients who underwent an appendectomy from January 1, 2005 to December 31, 2008. Current procedural terminology (CPT) codes for open appendectomy (44950, 44960, and 44900) and laparoscopic appendectomy (44970, 44979, 44950, 44960, and 44900) were cross-referenced with the primary diagnosis category to select for cases of acute appendicitis. For example, patients who underwent an incidental appendectomy in conjunction with another procedure were excluded. Cases of laparoscopic appendectomy converted to an open approach were isolated from the open procedure group by selecting for cases with secondary or other CPT codes indicating laparoscopic technique (by convention, NSQIP auditors initially record these as open cases and then add additional codes for laparoscopy).

Any operation that was commenced laparoscopically and converted was initially analyzed in the laparoscopic group on an

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intention-to-treat analysis. Subsequent subgroup analysis was also performed comparing the outcome of patients who underwent a laparoscopic to open conversion and patients who had the procedure completed laparoscopically. Operative variables such as emergency case, wound classification, American Society of Anesthesiologists (ASA) score, and duration of operative procedure were analyzed. An emergency case is defined in the NSQIP dataset as one that is performed no later than 12 hours after the patient has been admitted to the hospital. Perioperative outcomes such as postoperative sepsis, return to the operating room, and length of surgical stay were also examined. A surgical site infection is determined according to the Centers for Disease Control and Prevention (CDC) criteria.[10] Surgical site infections are classified as incisional (superficial or deep) infections or OSIs (intraperitoneal). Superficial and deep incisional infections were grouped together as incisional infections for the purposes of the univariate and multivariate analysis. OSIs were analyzed as a separate end-point. Only preoperative and intraoperative variables were used in the multivariate models to examine the variables of interest: postoperative incisional infection and organ space infection.

All analyses were carried out at the University of Rochester using SAS 9.2 (Copyright © 2009 SAS Institute Inc. Cary North Carolina 27513, USA) on a Windows XP Pro platform (Microsoft Corp.). Differences in the clinical characteristics of the patient groups based on operative procedure were assessed using a *t* test with pooled or unpooled variances or a Wilcoxon rank sum test or χ^2, as appropriate to the data. Surgical infections postappendectomy (OSI as well as incisional infection) were evaluated independently as binary outcomes, and the associations of operative approach and surgical risk factors with these outcomes were looked at in univariate (unadjusted) and multivariate (adjusted) logistic regressions. Those variables with a $P \leq 0.10$ in the univariate model were selected for inclusion in the multivariate logistic regressions. A regression model incorporating preoperative and intraoperative factors was used to evaluate the probability of infection for sample patient scenarios.

RESULTS

A total of 39,950 appendectomies were included overall, of which 23% (9375/39,950) were open appendectomies. Seventy-seven percent of cases (30,575) were commenced laparoscopically, of which 576 were converted to an open procedure, giving an overall conversion rate of 1.9% (576/30,575). The clinical characteristics and operative findings are outlined in Table 1. The overall rate of incisional wound infection was 2.5% (1001/39,950), with a significant difference between the open (5.2%) (489/9375) and laparoscopic (1.7%; 512/ 30,575) groups in an unadjusted analysis [odds ratio (OR 0.31, 95% CI 0.27–0.35, *P* 0.0001). A total of 77.8% of the incisional infections were diagnosed in the postdischarge period (779/1001) comprising 85.2% of the laparoscopic group (436/512) and 70.1% of the open group (343/489). The 30-day recorded rate of OSI was 1.8% (722/39,950). There was no significant difference in the rate of OSI between the open (1.9%) (175/9375) and the laparoscopic groups (1.8%) (547/30,575) in an unadjusted analysis (OR 0.96, 95% CI 0.81–1.14, $P = 0.62$). The postdischarge rate of OSI was 66.8% for the total group (482/722), with a rate of 70.6% in the laparoscopic group (386/547) and 54.9% in the open group (96/175).

Univariate analyses of patient characteristics and operative techniques associated with incisional infections and OSIs are outlined in Table 2. Despite differences in risk factors between patients who underwent laparoscopic intervention and those who had open surgery, laparoscopy was associated with a lower risk of incisional infection in the multivariate analysis (OR 0.37, 95% CI 0.32–0.43), even after adjusting for other significant factors including body mass index, history of diabetes, preoperative sepsis, operative wound class,

TABLE 1. Clinical Characteristics of the Patient Group Based on Operative Procedure

	Laparoscopic Group*	Open Group	*P*
Total group	30,575 (77%)	9375 (23%)	
Male gender, N (%)	15,623 (51.1%)	5305 (56.6%)	<0.0001
Mean age in years (± SD)	38 (± 16)	41 (± 18)	<0.0001
Mean body mass index (± SD)	27.5 (± 6.5)	27.2 (± 6.3)	<0.0001
History of diabetes mellitus, N (%)	1242 (4.1%)	483 (5.2%)	<0.0001
Steroid use for chronic condition, N (%)	235 (0.8%)	108 (1.2%)	<0.0001
Current smoker within 1 year, N (%)	6739 (22%)	2045 (21.8%)	0.64
Documented Sepsis			
SIRS, N (%)	9,973 (32.6%)	3358 (35.8%)	<0.0001
Sepsis, N (%)	435 (1.4%)	319 (3.4%)	
Septic shock, N (%)	47 (0.2%)	49 (0.5%)	
Mean preoperative serum WBC (± SD)	13.1 (± 4.6)	13.5 (± 4.7)	<0.0001
ASA class I, N (%)	11,164 (36.5%)	3,252 (34.7%)	<0.0001
ASA class II, N (%)	16,273 (53.2%)	4,709 (50.2%)	
ASA class III, N (%)	2,872 (9.4%)	1,224 (13.1%)	
ASA class IV, N (%)	220 (0.7%)	182 (1.9%)	
Emergency case, N (%)	22,834 (74.7%)	7,493 (79.9%)	<0.0001
Wound Class			
II, N (%)	11,599 (37.9%)	3,175 (33.9%)	<0.0001
III, N (%)	13,496 (44.1%)	3,028 (32.3%)	
IV, N (%)	5,480 (17.9%)	3,172 (33.8%)	
Median total operation time (25%, 75%)	47 (35, 63)	49 (36, 67)	<0.0001
Total operation time ≥ 60 min, n (%)	9039 (29.6%)	3137 (33.5%)	<0.0001
Postoperative sepsis, N (%)	329 (1.1%)	213 (2.3%)	<0.0001
Return to OR, N (%)	361 (1.2%)	213 (2.3%)	<0.0001
Mean length of total surgical stay (± SD)	1.8 (± 2.7)	2.3 (± 5.5)	<0.0001
Mean days from OR to discharge (± SD)	1.6 (± 2.6)	3.1 (± 4.5)	<0.0001

*The laparoscopic group includes cases that were converted to an open procedure (n = 575).
OR, operating room; SIRS, systemic inflammatory response syndrome.

and operative time (Table 3). The protective effect of laparoscopy for incisional infections was more pronounced in patients with wound class IV (n = 8,652; OR 0.33, 95% CI 0.26–0.41) than those in the wound class II and III cohort (n = 31,298, OR 0.41, 95% CI 0.34–0.49).

In contrast, laparoscopic intervention was associated with an increased risk of OSI in the multivariate analysis (OR 1.44, 95% CI 1.21–1.73) after adjusting for the other significant risk factors including male sex, preoperative sepsis, wound class, and operative time (Table 3). The deleterious association between the laparoscopic approach and OSI was seen for cases with wound class II or III (OR 1.67, 95% CI 1.18–2.46) and for wound class IV (OR 1.36, 95% CI 1.11–1.68) patients. The association between clinical factors and operative approach was also examined in a multivariate analysis for any type of surgical site infection as the outcome (cumulative events of

TABLE 2. Univariate Analysis of Clinical Factors and Operative Procedures Associated With Incisional and Organ Space Wound Infection

Variable	Incisional Infection, n = 1001	No Incisional Infection, n n= 38,941	*P*	Organ Space Infection, n = 722	No Organ Space Infection, n = 39,228	*P*
Laparoscopic technique, N (%)	512 (51.0%)	30,063 (77.2%)	<0.0001	547 (75.8%)	30,028 (76.6%)	0.62
Male gender, N (%)	576 (57.5%)	20,352 (50.9%)	0.009	439 (60.8%)	20,489 (52.2%)	<0.0001
Mean age in years (±SD)	43.2 (± 16.6)	38.6 (± 16.4)	<0.0001	41.6 (± 17.1)	38.7 (± 16.5)	<0.0001
Mean body mass index (±SD)	29.8 (± 7.8)	27.4 (± 6.4)	<0.0001	27.9 (± 6.3)	27.4 (± 6.5)	0.1
Diabetes mellitus, N (%)	103 (10.3%)	1622 (4.2%)	<0.0001	41 (5.7%)	1684 (4.3%)	0.07
Steroid use, N (%)	16 (1.6%)	327 (0.8%)	0.01	7 (1.0%)	336 (0.9%)	0.74
Bleeding disorder, N (%)	37 (3.7%)	821 (2.1%)	0.006	22 (3.1%)	836 (2.1%)	<0.0001
Current smoker within 1 year, N (%)	261 (26.1%)	8523 (21.9%)	0.0016	204 (28.3%)	8580 (21.9%)	<0.0001
Preoperative SIRS, N (%)	442 (44.2%)	12,889 (33.1%)	<0.0001	400 (55.4%)	12,931 (33.0%)	<0.0001
Preoperative sepsis, N (%)	41 (4.1%)	713 (1.8%)		37 (5.1%)	717 (1.8%)	
Preoperative septic shock, N (%)	6 (0.6%)	90 (0.2%)		5 (0.7%)	91 (0.2%)	
Mean preoperative WBC (±SD)	14.2 (± 4.7)	13.2 (± 4.7)	<0.0001	15.2 (± 4.8)	13.2 (± 4.6)	<0.0001
ASA class I, N (%)	255 (25.5%)	14,161 (36.4%)	<0.0001	203 (28.1%)	14,213 (36.3%)	<0.0001
ASA class II, N (%)	534 (53.5%)	20,448 (52.6%)		398 (55.1%)	20,584 (52.6%)	
ASA class (III/IV/V), N (%)	210 (21.0%)	4288 (11.0%)		121 (16.8%)	4377 (11.2%)	
Emergency case, N (%)	779 (77.8%)	29,548 (75.9%)	0.15	604 (83.7%)	29,723 (75.8)	<0.0001
Wound class II, N (%)	266 (26.6%)	14,508 (37.3%)	<0.0001	78 (10.8%)	14,696 (37.5%)	<0.0001
Wound class III, N (%)	316 (31.6%)	16,208 (41.6%)		173 (24.0%)	16,351 (41.7%)	
Wound class IV, N (%)	419 (41.9%)	8233 (21.1%)		471 (65.2%)	8181 (20.9%)	
Total operation time ≥60 min, N (%)	511 (51.1%)	11,665 (30.0%)	<0.0001	355 (49.2%)	11,821 (30.1%)	<0.0001
Mean length of total surgical stay (±SD)	3.9 (±5.1)	2.1(±3.6)	<0.0001	6.3(±6.5)	2.1(±3.5)	<0.0001
Mean days from operation to discharge (±SD)	3.8 (±5.1)	1.9(±3.2)	<0.0001	6.0(±6.3)	1.9(±3.1)	<0.0001

SIRS, systemic inflammatory response syndrome; WBC, white blood cell.

TABLE 3. Multivariate Analysis of Clinical Factors and Operative Procedures Associated With Incisional and Organ Space Wound Infection

	Incisional Infection		Organ Space Infection	
Variable	**OR (CI 95%)**	***P***	**OR (CI 95%)**	***P***
Laparoscopic technique (vs. open)	0.37 (0.32–0.43)	<0.0001	1.44 (1.21–1.73)	<0.0001
Male gender	1.12 (0.97–1.29)	0.1290	1.33 (1.14–1.55)	0.0004
Mean age in years	1.04 (0.99 –1.01)	0.0916	1.00 (0.99–1.01)	0.8676
Mean body mass index	1.03 (1.02–1.04)	<0.0001	–	–
History of diabetes mellitus	1.49 (1.15–1.92)	0.0024	0.94 (0.66–1.31)	0.7090
History smoking	1.09 (0.92–1.29)	0.34	1.24 (1.04–1.48)	0.0154
History bleeding disorder	1.05 (0.70–1.51)	0.8129	0.96 (0.59–1.50)	0.8854
SIRS	1.26 (1.08–1.48)	0.0040	1.49 (1.26–1.77)	<0.0001
Mean preoperative serum WBC count per 1000 WBC/mm^3	1.02 (1.01–1.04)	0.0162	1.03 (1.01–1.05)	0.0002
ASA class II vs. I	1.09 (0.92–1.32)	0.3090	1.15 (0.95–1.39)	0.1540
ASA class (III + IV + V vs. I)	1.18 (0.90–1.53)	0.2302	1.21 (0.90–1.60)	0.2013
Emergency case	–	–	1.31 (1.07–1.62)	0.0093
Wound class III vs. II	1.01 (0.84–1.22)	0.8981	1.76 (1.34–2.32)	<0.0001
Wound class IV vs. II	1.70 (1.39 –2.03)	<0.0001	7.90 (6.16–10.27)	<0.0001
Total operation time ≥60 min	1.89 (1.63–2.18)	<0.0001	1.53 (1.31–1.79)	<0.0001

SIRS, systemic inflammatory response syndrome; WBC, white blood cell.

incisional and OSI). The laparoscopic approach was associated with a lower rate of any infections (OR 0.63, 95% CI 0.56–0.71) compared with the open approach. This protective effect of laparoscopy was seen for wound class II/III (OR 0.58, 95% CI 0.49–0.69) and for wound class IV patients (OR 0.68, 95% CI 0.58–0.79).

A subgroup analysis was then performed comparing patients who had a procedure completed laparoscopically (n = 29,999) and those who underwent a conversion from a laparoscopic to open appendectomy (n = 576). Patients who underwent a conversion had a significantly higher rate of incisional infection (9.7%) compared with the completely laparoscopic group (1.5%) in the unadjusted analysis (OR 6.98, 95% CI 5.17–9.25, $P < 0.0001$). Similarly, the rate of OSI was markedly higher in the conversion group (4.2%) compared with the laparoscopic group (1.7%) in the unadjusted analysis (OR 2.45, 95% CI 1.57–3.64, $P < 0.0001$). The multivariate analysis revealed that patients who underwent a conversion were significantly more likely to develop an incisional infection than those undergoing a fully laparoscopic procedure independent of other risk factors (OR 3.28, 95% CI 2.3–4.59, $P < 0.0001$). Conversion from laparoscopic to open procedure, however, was not retained as a significant variable associated with an OSI (OR 0.83, 95% CI 0.52−1.25, P 0.40).

The multivariate model employing preoperative and intraoperative factors was then used to calculate the probability of subsequent OSI based on certain clinical scenarios (Table 4). To examine the association between conversion to an open procedure and subsequent OSI, a subgroup multivariate analysis was performed for patients who underwent a conversion. When examining 2 of the aforementioned clinical scenarios from Table 4 with this multivariate model, the probability of OSI for the 18-year-old male patient (Case 1a) was calculated to be 5.7% when undergoing a laparoscopic appendectomy converted to an open procedure. For the same conversion in surgical approach, the sample 23-year-old female patient (Case 2b) resulted in a 2.2% probability of OSI.

DISCUSSION

This study confirms the increasing utilization of the laparoscopic approach in the management of patients with appendicitis in accordance with previous reports.[11,12] Compared with patients who underwent laparoscopic appendectomy, more patients who underwent open appendectomy were male and older, had a higher incidence of comorbid conditions, had an increased rate of preoperative sepsis, had a higher ASA class, and were more likely to have a grossly contaminated wound (wound class IV). The choice of approach may have been influenced by diagnostic uncertainty in female patients or the wish to proceed to a perceived expedient open procedure in a floridly sick patient, although the lack of information on preoperative decision-making precludes drawing a definitive conclusion on reasons for one approach versus another. Because there are baseline clinical differences between patients in the laparoscopic and open group, it is essential to control for potential confounding factors when examining the relationship between operative approach and infectious complications.

A laparoscopic approach was associated with a reduced incidence of incisional infection for all wound classes independent of other risk factors and after controlling for the baseline differences between the laparoscopic and open groups. These data are consistent with those of reports from several large administrative and clinical datasets, although these reports tend to aggregate the more common incisional wound infection outcome with the less frequent but more serious adverse event of OSI.[13,14] Romy et al 2008 prospectively followed 2468 patients who underwent appendectomy (42.6% laparoscopic) with a similar postdischarge follow-up model and found that a laparoscopic approach was protective for incisional infection in accordance with our findings.[15]

In contrast to its protective relationship with incisional infection, we observed that the laparoscopic approach was independently associated with OSI compared with the open approach in the multivariate analysis. Romy et al noted that although OSI was higher in the laparoscopic group (3.5%) than in the open appendectomy group (2.5%) in an unadjusted analysis, laparoscopy was not retained in their multivariate model for factors associated with OSI. Their absence of a significant difference between the 2 operative approaches may reflect the smaller number of cases (n = 2,468) and of OSIs (n = 72) compared with our study cohort. An analysis of outcome postappendectomy from the German National Nosocomial Infections Surveillance System also found that laparoscopic appendectomy was independently associated with an increased risk of OSI (OR 2.31, 95% CI 1.29–4.13).[16]

The link between a laparoscopic approach and subsequent OSI has been disputed by other studies. In a multicenter series of 1017 patients with complicated appendicitis (gangrenous or perforated), Cueto et al reported similar postoperative abscess rates (7.4%) when comparing laparoscopically commenced cases with historical reports of OSI following open appendectomy.[6] Sleem et al studied 247 patients with confirmed perforated appendicitis, where 90% were commenced laparoscopically with a conversion rate of 15.7%.[7] The laparoscopic group had a markedly lower rate of incisional infection (5%) compared with the open group (18%), whereas the postoperative abscess rate was not significantly different: 13.4% laparoscopic versus 12.5% in the open group, mirroring the findings of other

TABLE 4. Clinical Patient Scenarios With Probability of OSI Stratified for by Laparoscopic (lap) and Open Approach (open)

Case	Sex	Age	Diabetes	Smoker	Bleeding Disorder	Preop Sepsis	Preop WBC	ASA Class	Emergency	Wound Class	OR Time minutes	Procedure	Probability OSI
1a	M	18	No	Yes	No	SIRS	15	1	Yes	IV	<60	Lap	7.1%
												Open	5.0%
1b	M	18	No	Yes	No	SIRS	15	1	Yes	IV	≥60	Lap	10.4%
												Open	7.4%
2a	F	23	No	No	No	None	13	1	Yes	II	<60	Lap	0.4%
												Open	0.3%
2b	F	23	No	No	No	None	13	1	Yes	IV	<60	Lap	2.8%
												Open	2.0%
3a	M	77	Yes	Yes	No	Sepsis	17	4	Yes	II	<60	Lap	1.2%
												Open	0.8%
3b	M	77	Yes	Yes	No	Sepsis	17	4	Yes	IV	<60	Lap	8.4%
												Open	6.0%
3c	M	77	Yes	Yes	No	Sepsis	17	4	Yes	IV	≥60	Lap	12.3%
												Open	8.9%

F, female; M, male; OR, operating room; preop, preoperative; SIRS, systemic inflammatory response syndrome; WBC, white blood cell.

institutional studies.[5,17] The difference in findings between our results and those of the studies noted earlier probably reflects the fact that a large dataset such as the NSQIP, with multiple clinical parameters on a large number of patients, is necessary to detect the relationship between OSI and laparoscopy while controlling for other confounding factors.

It is important to acknowledge certain limitations of the NSQIP dataset. For example, antibiotic prophylaxis information is not available. In addition, we have no information on the level of experience or subspecialty interest of the surgeons involved, but the low rate of conversion and shorter operation time in the laparoscopic group compared with the open approach would suggest a reasonable level of experience with the laparoscopic approach. Furthermore, this study population is not randomly selected and reflects the case mix of the hospitals that use the NSQIP system to audit their activity. Therefore, the findings may not be reflective of the case mix of hospitals across the United States.

Although the laparoscopic approach was associated with a risk reduction of 37% in all episodes of postappendectomy infection (cumulative incisional and organ space) on multivariate analysis, it would be inappropriate to attempt to offset the increase in OSIs with the reduction achieved in incisional infections by the laparoscopic approach. Given that all patient subgroups appear to benefit from a laparoscopic approach in terms of reduced incisional infection, the pertinent issue is whether certain patient subgroups exist whose increased risk of OSI supersedes any benefit in reduced incisional infections afforded by the laparoscopic approach. To help address this dilemma, multivariate models employing preoperative and intraoperative factors were employed to generate clinical scenarios exemplifying patient groups based on their probability of OSI.

Case 1a in Table 4 illustrates a typical presentation of perforated appendicitis in a young male patient with resulting differences in probability of OSI for the 2 surgical approaches. Case 1b shows the association of increased operative time (>60 minutes) with an increase in probability of infection for both the laparoscopic and open techniques. Similarly, cases 2a and 2b demonstrate the increase in probability of infection with only a change in the operative wound class for the 23-year-old female patient. Case 3 describes an elderly male patient with a number of preoperative risk factors for OSI, and the breakdown of the 3 scenarios for this gentleman show how probability for this complication changes across the spectrum of wound class and operative duration.

Interestingly, although both of these sample patients display clinical pictures typical for acute appendicitis, the differences of male sex, smoking status, preoperative sepsis, and increased white blood cell count make the patient in case 1a almost 3-fold more predisposed to OSI compared with the patient described in Case 2b. For both patients, there is a reduced probability of OSI following conversion from a laparoscopic to an open approach as compared with a completely laparoscopic approach (5.7% and 2.2%, respectively, for Case 1a and Case 2b). Of note, both patients were selected for this predictive model because they represent realistic situations of conversion from laparoscopy to open techniques given a grossly contaminated operative field (wound class IV), likely due to preoperative appendiceal perforation.

The reduction in probability of OSI is approximately 1.0% for the young male patient versus a reduction of approximately 0.5% for the female patient. This suggests that conversion to an open approach may result in different degrees of reduction in the rate of OSI depending on the initial probabilities of intraperitoneal infection. The clinical scenarios generated are meant to be representative, demonstrating that patients can be broadly stratified into different risk profiles for OSI. This stratification may aid in clinical decision-making and patient counseling regarding the infrequent but significant complication of OSI.

The strong association between wound class IV and OSI raises the issue of whether such patients would benefit from a primary open procedure or early conversion from laparoscopy, possibly reducing their risk of OSI. In terms of the choice for a primary open procedure, prediction of wound contamination is problematic. Accurate preoperative diagnosis of perforated appendicitis is challenging as computed tomography findings of appendiceal abscess and extraluminal gas are associated with a high specificity (98% and 99%) but a low sensitivity (34% to 35%) in relation to perforated appendicitis.[18] In terms of considering conversion from laparoscopic to open approach, the multivariate analyses of the current study imply a link between the perioperative factors and OSI but do not prove causation. Secondly, although there was an independent association between operative time and OSI for the subgroup of patients who underwent a converted procedure compared with patients who had the case completed laparoscopically, it is not possible to say at what stage or why cases were converted. Therefore, it is not possible to conclude that an early conversion to an open procedure is preferable to completing the case laparoscopically in a patient with grade IV contamination.

In conclusion, a laparoscopic approach, sex, smoking, preoperative sepsis, wound class, and operative time were all associated with OSI postappendectomy. With the influence of these different clinical variables, the risk of OSI with laparoscopic appendectomy will, therefore, vary depending on particular patient scenarios. Given the demonstrated benefit of laparoscopy for incisional infections postappendectomy in all scenarios, the findings from this study can aid clinicians in balancing both categories of infectious risk to choose the most appropriate operative technique for their patients.

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