ONLINE FIRST

Surgical Site Infections in Colon Surgery

The Patient, the Procedure, the Hospital, and the Surgeon

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Objective: To determine the role of the surgeon in the occurrence of surgical site infection (SSI) following colon surgery, with respect to his or her adherence to guidelines and his or her experience.

Design, Setting, and Patients: Prospective cohort study of 2393 patients who underwent colon surgery performed by 31 surgeons in 9 secondary and tertiary care public Swiss hospitals, recruited from a surveillance program for SSI between March 1, 1998, and December 31, 2008, and followed up for 1 month after their operation.

Main Outcome Measures: Risk factors for SSI were identified in univariate and multivariate analyses that included the patients' and procedures' characteristics, the hospitals, and the surgeons as candidate covariates. Correlations were sought between surgeons' individual adjusted risks, their self-reported adherence to guidelines, and the delay since their board certification.

Results: A total of 428 SSIs (17.9%) were identified, with hospital rates varying from 4.0% to 25.2% and individual surgeon rates varying from 3.7% to 36.1%. Features of the patients and procedures associated with SSI in univariate analyses were male sex, age, American Society of Anesthesiologists score, contamination class, operation duration, and emergency procedure. Correctly timed antibiotic prophylaxis and laparoscopic approach were protective. Multivariate analyses adjusting for these features and for the hospitals found 4 surgeons with higher risk of SSI (odds ratio [OR]=2.37, 95% confidence interval [CI], 1.51-3.70; OR=2.19, 95% CI, 1.41-3.39; OR=2.15, 95% CI, 1.02-4.53; and OR=1.97, 95% CI, 1.18-3.30) and 2 surgeons with lower risk of SSI (OR=0.43, 95% CI, 0.19-0.94; and OR=0.19, 95% CI, 0.04-0.81). No correlation was found between surgeons' individual adjusted risks and their adherence to guidelines or their experience.

Conclusion: For reasons beyond adherence to guidelines or experience, the surgeon may constitute an independent risk factor for SSI after colon surgery.

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SURGICAL SITE INFECTIONS (SSIs) constitute about a quarter of all nosocomial infections and affect up to 5% of surgical patients, with the highest rates (about 20%) being reported in colorectal surgery.[1-11] Surgical site infection entails a longer hospital stay by about 10 days and a 2- to 3-fold increase in costs.[4,6,12-16] It is an independent predictor of mortality in surgical patients.[17] American and European guidelines have been issued, providing evidence-based recommendations for the prevention of SSI.[1,2,18]

Acknowledged risk factors for SSI, whether modifiable or not, are related to the patient or the intervention. Patient-related risk factors include age, severe comorbidity, diabetes, obesity, smoking, malnutrition, steroid use, and immunosuppression.[2,10,19-22] Procedure-related risk factors include antibiotic prophylaxis, oxygen supply, fluid management, bowel preparation, and skin disinfection.[2,8,10,23-26] Arguably, the surgeon constitutes the single most important risk or protective factor for SSI. However, his or her role in the origin of SSI has not yet been explored in detail.[10,27-31] For example, little is known about the surgeon's actual adherence to guidelines and the impact it can have on the SSI rates of his or her patients.

The aims of this study were, first, to determine the role of the surgeon in the occurrence of SSI following colon surgery and, second, to investigate whether his or her adherence to guidelines and/or experience were associated with his or her individual risk for SSI.

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METHODS

PARTICIPANTS AND DATA COLLECTION

The data used for this study were collected prospectively from March 1, 1998, to December 31, 2008, in a multicentric surveillance program for SSI from Western and Southern Switzerland. This program, based on the principles of the US National Healthcare Safety Network, previously known as the National Nosocomial Infections Surveillance System,[32,33] includes a systematic postdischarge follow-up at 1 month performed through telephone interviews with the patients by trained infection control nurses who seek additional information from family or hospital physicians when an SSI is suspected. Diagnoses of SSI are confirmed by infectious disease physicians according to the Centers for Disease Control and Prevention definitions and classified as incisional (superficial or deep) or organ/space infections.[7] For this study, we used data related to colon surgery only.

The variables collected by the surveillance program included the hospital in which the interventions took place, the surgeons who performed them, characteristics of the patients (sex, age, American Society of Anesthesiologists [ASA] score, delay from admission to operation), and characteristics of the interventions (contamination class, duration of the intervention compared with the T time as defined in the National Nosocomial Infections Surveillance System index [3 hours for colon surgery],[33] emergency procedure, antibiotic prophylaxis ≤1 hour before the incision, laparoscope use, multiple procedures during the colon surgery, reintervention within a month for noninfectious complications).

In addition, a questionnaire presented elsewhere,[34] based on the British National Institute for Health and Clinical Excellence guideline,[1] was sent in 2008 to surgeons with more than 30 colon surgery procedures followed up in the surveillance program and who were working in the participating hospitals. Their answers were compared with the recommendations of the National Institute for Health and Clinical Excellence guideline, and an adherence score was built for each surgeon by weighting on a 3-level scale (0, 0.5, or 1 point) the questionnaire's items according to their level of evidence and their presumable impact on SSI rates. The maximal score, obtained by summing the points for each weighted item, was 18, meaning full adherence to evidence-based recommendations.

STATISTICAL ANALYSIS

A global SSI rate was calculated for all of the colon operations performed by the surgeons who answered the questionnaire. Specific SSI rates were calculated for each hospital in which these surgeons were working and for each answering surgeon. The correlation between surgeons' individual overall SSI rates (incisional and organ/space SSIs) and their rates of organ/space SSIs alone was established.

Risk factors for SSI were determined by comparing patients who developed an SSI with those who did not. Fisher exact test, Mantel-Haenszel test, *t* test, and Wilcoxon rank sum test were used as appropriate for univariate analyses. Multivariate logistic regression models were used to adjust for confounding factors. First, a general model was built using a forward stepwise procedure including risk factors with $P < .20$ in univariate analyses as candidate covariates together with all dummy-coded hospitals and surgeons. Second, individual multivariate models were built for each surgeon as compared with all of the others, including risk factors with $P < .20$ in univariate analyses as candidate covariates. The resulting adjusted odds ratios (ORs) for SSI of each surgeon were then plotted against his or her individual score of adherence to guidelines and against the time since his or her board certification, looking for potential correlations using the Spearman coefficient.

Data were entered into Epi Info software (World Health Organization, Geneva, Switzerland; and Centers for Disease Control and Prevention, Atlanta, Georgia). Statistical analyses were performed with SAS version 9.1 statistical software (SAS Institute, Inc, Cary, North Carolina). All tests were 2-tailed. $P < .05$ was considered statistically significant.

RESULTS

Thirty-one of 39 surgeons (79.5%) from 9 hospitals answered the questionnaire. Nine surgeons worked in 1 university hospital and 22 worked in 8 different regional public hospitals. They performed 2393 colon operations (in 2393 patients; mean, 77 colon operations; range, 32-188 colon operations) that were used for the identification of risk factors for SSI. A complete 1-month follow-up was available for 96.1% of the procedures. Overall, SSIs were found in 428 of 2393 interventions (17.9%): 274 were incisional SSIs and 154 were organ/space SSIs. The diagnosis was established after discharge for 97 of 428 SSIs (22.7%).

Table 1 shows the characteristics of the included patients and interventions and the results of the univariate analyses of risk factors for SSI. Male sex, older age, higher ASA score, higher contamination class, procedures lasting longer than 3 hours, emergency procedures, and antibiotic prophylaxis not properly timed were significantly associated with SSI, whereas the use of a laparoscope was significantly protective.

Crude SSI rates of the 9 studied hospitals were as follows: hospital A, 52 of 282 procedures (18.4%; 95% confidence interval [CI], 13.9-23.0); hospital B, 105 of 417 procedures (25.2%; 95% CI, 21.0-29.4); hospital C, 123 of 610 procedures (20.2%; 95% CI, 17.0-23.3); hospital D, 73 of 375 procedures (19.5%; 95% CI, 15.5-23.5); hospital E, 16 of 298 procedures (5.4%; 95% CI, 2.8-7.9); hospital F, 3 of 76 procedures (4.0%; 95% CI, 0.0-8.3); hospital G, 19 of 140 procedures (13.6%; 95% CI, 7.9-19.2); hospital H, 9 of 70 procedures (12.9%; 95% CI, 5.0-20.7); and hospital I, 28 of 125 procedures (22.4%; 95% CI, 15.1-29.7). When the rates of each of them were compared with the overall rate of the 8 others in unadjusted analyses (Fisher exact tests), rates in hospitals B, E, and F were significantly different.

Crude SSI rates of individual surgeons varied from 3.7% (95% CI, 0.8-6.6) to 36.1% (95% CI, 26.5-45.6) for incisional and organ/space SSIs and from 0.0% to 14.4% for organ/space SSIs alone. These 2 individual rates were highly correlated (Spearman coefficient = 0.77; $P < .001$). When the rates of each surgeon (incisional and organ/space SSIs) were compared with the overall rate of all of the 30 others in unadjusted analyses (Fisher exact tests), 4 had significantly higher rates (surgeons 4, 5, 14, and 16) and 4 had significantly lower rates (surgeons 19, 20, 22, and 26).

The results of the final general multivariate logistic regression model, adjusting for risk factors linked to the patients, the procedures, or the hospital, are presented in **Table 2**. Four of the 31 surgeons (surgeons 2, 5, 16, and 29, but no longer surgeons 4 and 14) were independently associated with SSI, whereas 2 of them (surgeons 1 and 26, but no longer surgeons 19, 20, and 22) had an independent preventive effect on SSI. Similarly, hospitals E and F remained protective for SSI, but hospital B was no longer significantly associated with SSI. Other in-

Table 1. Patients' and Interventions' Characteristics by Occurrence of Surgical Site Infection

Characteristic	SSI (n=428)	No SSI (n=1965)	*P* Value[a]
Women, No. (%)	185 (43.2)	1014 (51.6)	.002
Age, mean (SD), y	68.2 (14.9)	65.8 (14.9)	.02
ASA score, No. with SSI/total No. (%)			
1	27/247 (10.9)		
2	227/1294 (17.5)		
3	147/707 (20.8)		.006
4	27/137 (19.7)		
5	0/8 (0.0)		
Delay from admission to operation, mean (SD), d	3.7 (14.8)	3.1 (7.7)	.78
Contamination class, No. with SSI/total No. (%)			
2	261/1691 (15.4)		
3	55/314 (17.5)		<.001
4	112/388 (28.9)		
Duration >3 h, No. (%)	188 (43.9)	716 (36.4)	.004
Emergency procedure, No. (%)	112 (26.2)	290 (14.7)	<.001
Antibiotic prophylaxis ≤1 h before incision, No. (%)	312 (72.9)	1608 (81.8)	<.001
Laparoscope use, No. (%)	49 (11.5)	484 (24.6)	<.001
Multiple procedures during same intervention, No. (%)[b]	92 (21.5)	410 (20.9)	.79
New operation ≤1 mo for noninfectious complications, No. (%)	34 (7.9)	127 (6.5)	.28

Abbreviations: ASA, American Society of Anesthesiologists; SSI, surgical site infection.
[a] Fisher exact test, Mantel-Haenszel test, *t* test, or Wilcoxon rank sum test.
[b] Other procedures performed during colon surgery were as follows: 35 appendectomies, 20 biliary tract operations, 107 cholecystectomies, 34 small-bowel operations, 75 herniorrhaphies, 19 hysterectomies, 57 genitourinary tract operations, and 190 other digestive tract procedures.

Table 2. Multivariate Analysis of Risk Factors for Surgical Site Infections After Colon Surgery[a]

Risk Factor	Odds Ratio (95% CI)	*P* Value
Surgeon No.		
1	0.43 (0.19-0.94)	.04
2	1.97 (1.18-3.30)	.01
5	2.37 (1.51-3.70)	<.001
16	2.19 (1.41-3.39)	<.001
26	0.19 (0.04-0.81)	.02
29	2.15 (1.02-4.53)	.04
Hospital designator		
E	0.23 (0.14-0.39)	.03
F	0.28 (0.09-0.90)	<.001
Patients' characteristics		
Female	0.66 (0.53-0.83)	<.001
Age[b]	1.01 (1.00-1.02)	.02
Interventions' characteristics		
Contamination class	1.34 (1.15-1.57)	<.001
Duration >3 h	1.53 (1.22-1.93)	<.001
Emergency procedure	1.56 (1.14-2.13)	.005
Laparoscope use	0.39 (0.28-0.55)	<.001

Abbreviation: CI, confidence interval.
[a] Candidate covariates included in the forward stepwise procedure were as follows: the 31 surgeons and the 9 hospitals (the surgeon and the hospital with the largest denominators being the references for dummy coding), sex, age, American Society of Anesthesiologists score, contamination class, duration of the operation being longer than 3 hours, emergency procedure, antibiotic prophylaxis within 1 hour before the incision, and laparoscopic approach.
[b] Risk increase for each additional year.

dependent risk factors for SSI were the patient's age and sex (female being protective), interventions performed as emergency procedures, procedures lasting longer than 3 hours, and a high contamination class. The laparoscopic approach was protective.

Surgeons' individual adjusted ORs for SSI, not taking the hospital into account, are displayed in **Figure 1**. They varied from 2.53 (95% CI, 1.63-3.95) to 0.16 (95% CI, 0.07-0.37). The 4 surgeons with the highest ORs and lower limits of their 95% CIs above 1 (surgeons 2, 5, 16, and 29) were the same as those identified in the general model. They worked in 4 different hospitals, and 2 of them had also been identified in unadjusted comparisons. In contrast, only 2 of the 5 surgeons with the lowest ORs and upper limits of their 95% CIs below 1 (surgeons 1, 19, 20, 22, and 26) had been detected by the general model. The 3 who were no longer detected (surgeons 19, 20, and 22) worked in hospitals E and F, which had been identified as independent protective factors for SSI in the general model, suggesting that the effect of these 3 surgeons could have been confounded by the effect of the hospitals themselves.

The correlations between surgeons' individual ORs for SSI and their adherence to guidelines, as reflected by the score built from their answers to the questionnaire, and their experience, as reflected by their years of activity since their board certification, are shown in **Figure 2**. The Spearman coefficients for these 2 correlations were −0.16 ($P = .39$) and −0.20 ($P = .30$) respectively, suggesting that other factors linked to the surgeon might play a role in the occurrence of SSI.

COMMENT

This study demonstrates that surgeons themselves can be considered risk factors or protective factors for SSI, independent of other factors linked to the patient, the procedure, or the hospital where the intervention took place. Indeed, 6 of the 31 included surgeons remained significantly associated with SSI (whether positively or

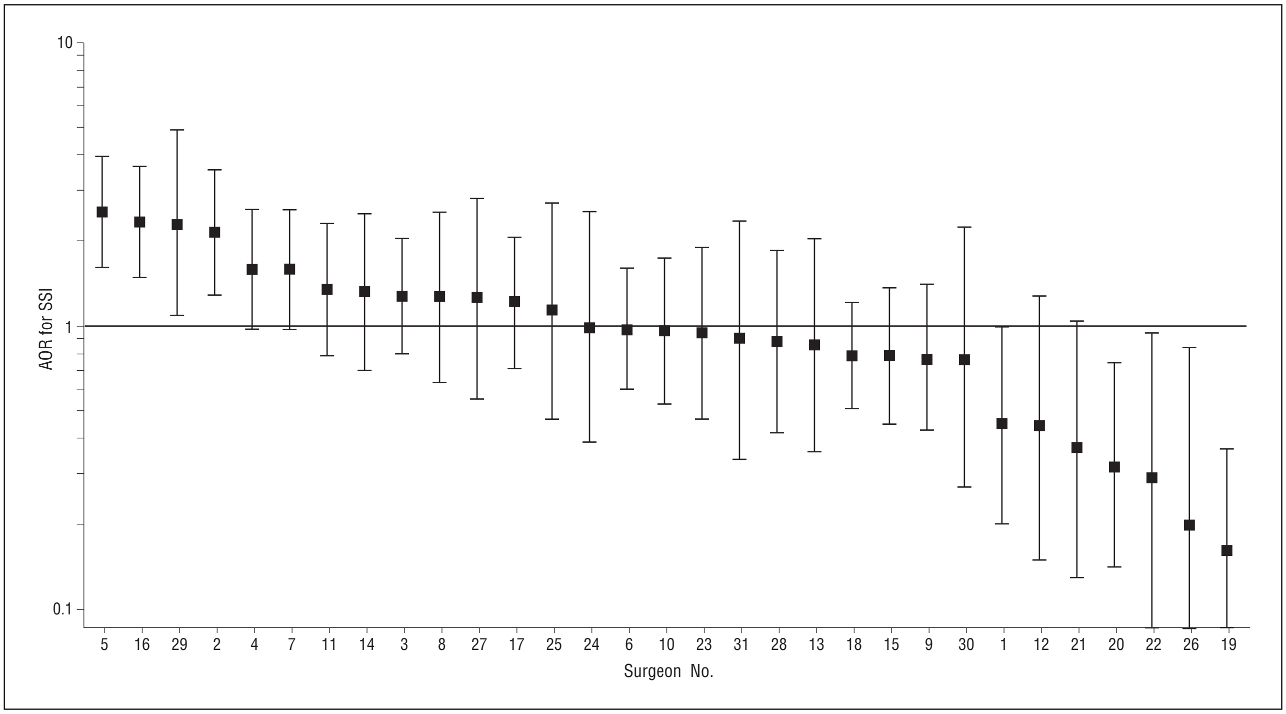

Figure 1. Surgeons' individual adjusted odds ratios (AORs) for surgical site infection (SSI) after colon surgery, adjusted for patients' sex and age, American Society of Anesthesiologists score, interventions' class of contamination and duration (>3 hours), emergency, laparoscopic approach, and properly timed antibiotic prophylaxis (≤1 hour before the incision). Error bars indicate 95% confidence interval.

negatively) in a multivariate model including all of them as candidate covariates and adjusting for the hospitals with which they were affiliated as well as for common risk factors identified by univariate analyses such as the patient's age, sex, and ASA score, the duration and contamination class of the intervention, emergency procedure, antibiotic prophylaxis, and the use of a laparoscope.

This raises the question, why do some surgeons represent an increased risk for SSI, while others are not significantly associated with SSI or are even protective? With no significant correlations having been found in this study between surgeons' individual risks for SSI and their self-reported adherence to evidence-based guidelines or their experience, other factors linked to the surgeon must have an impact on the occurrence of SSI.

Adherence to guidelines among surgeons included in this study, as reflected by the score built from their answers to a standardized questionnaire, was moderate with individual scores ranging from 7 to 14.5 points (median, 11 points) for a maximum of 18 points. This rather disappointing result might in part be due to the low level of scientific evidence supporting some items of published guidelines or to the lack of detailed recommendations regarding some technical aspects.[15,28,35,36] However, in this study and in others,[15,28,37] it has been found that even solidly established recommendations have not been consistently applied. In contrast to our findings, noncompliance to guidelines has been previously recognized as a predictor of bad outcomes in colorectal surgery.[31] Nevertheless, a recent retrospective cohort study of 405 720 surgical patients from 398 US hospitals (3996 SSIs) could not demonstrate that adherence to any of the 6 infection-prevention process-of-care measures from the Surgical Care Improvement Project protocol (including adequate antibiotic prophylaxis [timing, drug, duration], glucose control for cardiac surgery patients, adequate hair removal, and postoperative normothermia for colorectal surgery patients) could reduce the risk of SSI.[27,37] Moreover, a recent randomized trial comparing standard measures with extensive antiseptic measures in 1032 surgical patients did not find differences in SSI rates of the 2 groups, but it did show that lapses in discipline in the operating room during surgery were independently associated with SSI.[30] In accordance with our results, these recent publications suggest that the surgeon's impact is insufficiently reflected by his or her mere adherence to preventive measures for SSI.

Most of the surgeons in our study were experienced (delay since board certification: median, 16 years; range, 1-28 years), but the younger, less experienced surgeons did not have higher risks for SSI than the older, more experienced surgeons. They also were not more compliant with guidelines.[34] Probably better reflecting the experience than the time elapsed since board certification, a high operation volume has been associated with a lower risk for SSI in some studies.[29,38] Although detailed data about surgical volumes were not available in our study, we did not observe such a clear association at the hospital level or at the surgeon level.

Differences in SSI rates between hospitals could be due to several factors and may have an impact on surgeons' individual rates. This might explain why 3 surgeons who had a significantly lower individual risk for SSI were not retained in the general multivariate model that included their hospital as a covariate. Whereas differences in technical equipment are unlikely in wealthy countries, dif-

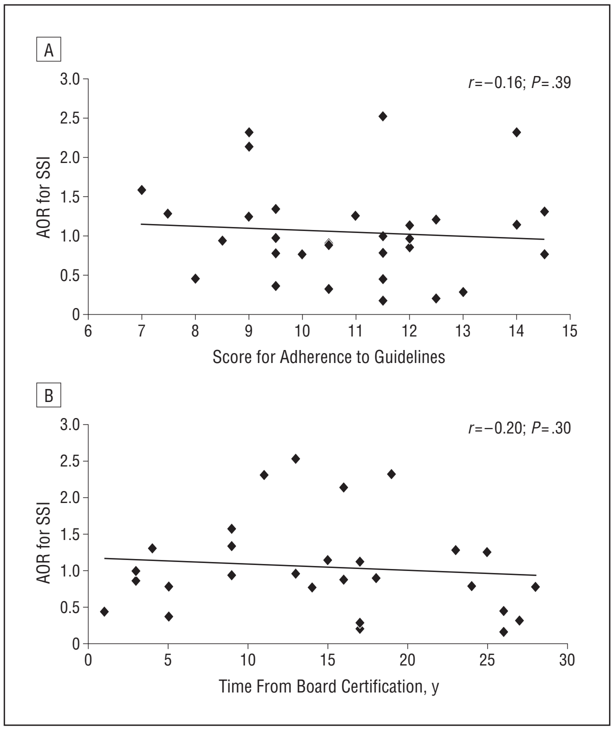

Figure 2. Correlations between surgeons' individual adjusted odds ratios (AORs) for surgical site infection (SSI) and their adherence to guidelines (A) and years of activity since their board certification (B).

ferences in nursing care or anesthesiology procedures may favor surgeons working in a hospital with stringent policies for the prevention of SSI.[24] In addition, failure to detect cases of SSI in a given hospital may create artificial differences between surgeons operating in this hospital and those working elsewhere. Indeed, although standardized definitions of SSIs, postdischarge follow-up, and dedicated personnel other than the surgeons themselves are all important factors to get reliable results from a surveillance system, to effectively decrease the risks of SSI,[39-42] audits are necessary for the validation of case detection in a setting of interhospital comparisons.[43]

The respective roles of hospitals and surgeons in SSI rates also raise the issue of the meaning of comparing hospitals between them, as is being increasingly requested by stakeholders of the health care system. Indeed, as demonstrated by our study, some hospitals are not at higher risk for SSI, whereas surgeons working in these institutions may be independently associated with higher rates of SSI.

Surgical skills are difficult to assess and might include discipline in the operating room, communication, and teamwork.[30,44,45] However, as recognized by surgeons themselves,[36] these skills must play an essential role in the occurrence of SSI and could explain, at least partly, why some surgeons have higher or lower SSI rates than others, irrespective of their patients' or interventions' characteristics and the hospital in which they work. We believe our findings confirm this hypothesis, as reported by others.[10,31,46]

Besides the surgeons and the hospitals, other independent risk factors for SSI were identified in this study: older age of the patient, high contamination class, operation lasting longer than 3 hours, and emergency procedure.[1,2,6,10,19-22] The laparoscopic approach was found to be protective, in accordance with our previous findings.[5] Despite the lack of a clear explanation, male sex was independently associated with SSI, as observed in 2 recent publications.[47,48] This could be confounded, for example, by cancer or smoking habits, 2 potential risk factors that were not available in our own database for adjustment and that could be more prevalent in men. Surprisingly, the ASA score and the administration of antibiotic prophylaxis were significantly associated with SSI in univariate analyses but not retained as independent risk factors in the multivariate model, meaning that they could have been confounded by other factors such as the emergency procedure, the surgeons, or the hospitals.

Several limitations of this study need to be addressed. First, although patients' follow-up and case detection were standardized and made by dedicated, trained, and independent observers, underreporting in some hospitals could not be excluded in the absence of an external validation system. Second, not all potential confounding factors such as patients' body mass index, comorbidities, smoking habits, or medications were available for multivariate analyses. On the other hand, the patient population was homogeneously distributed between hospitals and surgeons, whose specializations were similar. This is also true for the university hospital, which is both a secondary regional hospital and a referral tertiary care center. Third, surgeons' adherence to guidelines was assessed by a questionnaire and not by direct observation of their practice. However, their quite low self-reported adherence and the almost gaussian distribution of the score built from their answers both suggest the reliability of these data.

In conclusion and after analysis of 2393 colonic operations, although SSIs are associated with multiple factors, the surgeon constitutes the mainstay for their prevention. For this purpose, surgeons can rely on published evidence-based guidelines, but their mere adherence to such guidelines may be insufficient without good surgical skills. As highlighted by van Hove et al, we believe that reliable assessment methods of surgical skills are essential for trainees, teachers, and practicing surgeons "in an era with intense focus on training, and on quality and safety of surgery."[44]

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