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Laparoscope use and surgical site infections in digestive surgery

THESE

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INFLUENCE DE LA LAPAROSCOPIE SUR LES INFECTIONS DU SITE CHIRURGICAL EN CHIRURGIE DIGESTIVE

(Laparoscope use and surgical site infections in digestive surgery)

But: comparer les taux d'infections du site chirurgical (ISC) en fonction de la voie d'abord, ouverte ou laparoscopique, pour 3 procédures : l'appendicectomie, la cholécystectomie et la colectomie. Evaluer l'effet de la laparoscopie sur l'ISC pour ces trois interventions.

Contexte : la laparoscopie est associée à de nombreux avantages par rapport à la chirurgie ouverte. Parmi ceux-ci, des taux inférieurs d'ISC ont été rapportés lors de laparoscopie. Ceci a été décrit en particulier lors de cholécystectomie. Mais des biais tels que le manque de suivi après la sortie de l'hôpital, et certains facteurs confondants, auraient pu contribuer à l'observation de différences entre ces deux techniques.

Méthode : étude descriptive basée sur des données collectées entre mars 1998 et décembre 2004 de manière prospective dans le cadre d'un programme de surveillance des ISC dans 8 hôpitaux suisses. Ce programme comportait un suivi standardisé après le départ de l'hôpital. Les taux d'ISC ont été comparés après interventions faites par laparoscopie et chirurgie ouverte. Différents paramètres pouvant influencer la survenue d'une infection ont été identifiés en utilisant des modèles de régression logistiques.

Résultats : les taux d'ISC après interventions par laparoscopie et par voie ouverte ont été respectivement de 59/1051 (5.6%) versus 117/1417 (8.3%) après appendicectomie ($p = 0.01$), 46/2606 (1.7%) versus 35/144 (7.9%) après cholécystectomie ($p < 0.0001$), et 35/311 (11.3%) versus 400/1781 (22.5%) après colectomie ($p < 0,0001$). Après ajustement, les interventions par laparoscopie étaient associées à un taux inférieur d'ISC : odds ratio = 0.61 (IC 95% : 0.43 – 0.87) pour l'appendicectomie, 0.27 (0.16 – 0.43) pour la cholécystectomie et 0.43 (0.29 – 0.63) pour la colectomie.

Discussion et conclusion : bien que les patients aient quitté plus tôt l'hôpital après une intervention laparoscopique, leur suivi à un mois a été identique, ce qui a permis d'éviter une sous-estimation des ISC après chirurgie laparoscopique. De plus, l'analyse multivariée a inclus de nombreux facteurs potentiellement confondants, et l'utilisation de la laparoscopie était indépendamment et significativement liée à un effet protecteur à l'égard de l'ISC. La laparoscopie lors d'appendicectomie, cholécystectomie et colectomie semble diminuer le taux d'ISC en comparaison à la même chirurgie pratiquée par voie ouverte. Lorsqu'elle est faisable, cette voie d'abord minimalement invasive devrait être préférée à la chirurgie ouverte.

Laparoscope Use and Surgical Site Infections in Digestive Surgery

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Objective: To compare surgical site infection (SSI) rates in open or laparoscopic appendectomy, cholecystectomy, and colon surgery. To investigate the effect of laparoscopy on SSI in these interventions.

Background: Lower rates of SSI have been reported among various advantages associated with laparoscopy when compared with open surgery, particularly in cholecystectomy. However, biases such as the lack of postdischarge follow-up and confounding factors might have contributed to the observed differences between the 2 techniques.

Methods: This observational study was based on prospectively collected data from an SSI surveillance program in 8 Swiss hospitals between March 1998 and December 2004, including a standardized postdischarge follow-up. SSI rates were compared between laparoscopic and open interventions. Factors associated with SSI were identified by using logistic regression models to adjust for potential confounding factors.

Results: SSI rates in laparoscopic and open interventions were respectively 59/1051 (5.6%) versus 117/1417 (8.3%) in appendectomy ($P = 0.01$), 46/2606 (1.7%) versus 35/444 (7.9%) in cholecystectomy ($P < 0.0001$), and 35/311 (11.3%) versus 400/1781 (22.5%) in colon surgery ($P < 0.0001$). After adjustment, laparoscopic interventions were associated with a decreased risk for SSI: OR = 0.61 (95% CI 0.43–0.87) in appendectomy, 0.27 (0.16–0.43) in cholecystectomy, and 0.43 (0.29–0.63) in colon surgery. The observed effect of laparoscopic techniques was due to a reduction in the rates of incisional infections, rather than in those of organ/space infections.

Conclusion: When feasible, a laparoscopic approach should be preferred over open surgery to lower the risks of SSI.

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Various advantages have been reported for laparoscopic interventions when compared with open surgery. These include a shorter hospital stay after surgery, a faster recovery time, and a lower rate of surgical site infections (SSI).[1–3] However, biases and confounding factors associated with observational studies may have contributed to the observed differences in these outcomes. For instance, as pointed out by Richards et al,[3] the lack of postdischarge follow-up might generate a more important underestimation of SSI rates in patients who underwent laparoscopic procedures because they left the hospital earlier as those who underwent open surgery.

This study established the effect of a laparoscopic approach on SSI rates in appendectomy, cholecystectomy, and colon surgery, while using the variables available through a multicentric surveillance program that included postdischarge follow-up.

METHODS

From March 1998 to December 2004, patients undergoing appendectomy, cholecystectomy, or colon surgery in 8 hospitals in Western Switzerland (7 secondary care public hospitals and 1 tertiary care university hospital) were included in a surveillance program developed according to the principles of the U.S. National Nosocomial Infections Surveillance (NNIS) system.[4]

Demographic and clinical data were prospectively collected by trained infection control nurses. They included the hospital in which the patient was operated, age, gender, score of the American Society of Anesthesiologists (ASA), dates of admission and discharge, date and type of operation (procedure, emergency, laparoscopic approach), administration of prophylactic antibiotics, incision contamination class, duration of the intervention (longer or shorter as a T time, as defined in the NNIS index),[4,5] and whether a reintervention for another reason than SSI was performed during the follow-up period. Operations that began with a laparoscope and ended up as open surgery were considered as open surgery. Patients were followed-up during their hospital stay and postdischarge for a month. Postdischarge follow-up consisted of standardized phone interviews with the patients. Treating physicians were contacted for complementary information in case of answers that could suggest an SSI. Diagnoses of SSI were confirmed by infectious disease physicians according to the Centers for Disease Control and Prevention (CDC) definitions.[6,7] SSIs were classified as incisional (superficial or deep) or organ/space infections.

Data were entered in Epi-info (World Health Organization [WHO], Geneva and CDC, Atlanta). Statistics were done with the SAS software (Release 8.2, SAS Institute, Cary, NC). SSI rates, mean lengths of stay, and proportions of interventions with an available 1-month follow-up were compared between surgical techniques (laparoscopic or open procedures). Risk factors for SSI were determined by comparing patients who suffered from SSI with those who did not. Statistically significant risk factors for SSI were then compared between patients who underwent laparoscopic procedures and those who were operated using open surgery. Fisher exact, χ^2, Mantel-Haenszel, t, or Wilcoxon tests were used as appropriate for univariate analyses. Adjustment for confounding factors was done by including all available potential risk factors for SSI as candidate covariates in forward stepwise logistic regressions with $P \leq 0.2$ being the criteria for entry into the model and $P \leq 0.05$ being the criteria for remaining in it. All SSI, incisional SSI, and organ/space SSI were analyzed separately. Hospitals were dummy-coded and hospital F was considered the reference. All tests were 2-tailed. $P \leq 0.05$ was considered significant.

RESULTS

The included interventions were 2468 appendectomies, of which 1051 (42.6%) were performed with a laparoscope, 3096 cholecystectomies, of which 2652 (85.6%) were performed with a laparoscope, and 2092 operations of the colon, of which 311 (14.9%) were performed with a laparoscope. The median lengths of stay in laparoscopic and open interventions were respectively 4 days (interquartile range, IQR = 3) versus 5 days (IQR = 3) in appendectomy ($P < 0.0001$), 5 days (IQR = 3) versus 11 days (IQR = 8) in cholecystectomy ($P < 0.0001$), and 10 days (IQR = 5) versus 16 days (IQR = 11) in colon surgery ($P < 0.0001$). Follow-up at 1 month was available in 976/1051 (92.9%) of the appendectomies done

TABLE 1. Appendectomy: Characteristics of Patients and Surgical Interventions, Risk Factors for SSI (Univariate Analysis)

Characteristic	Total (n = 2468)	SSI (n = 176)	No SSI (n = 2292)	P
Male gender, N (%)*	1331 (53.9)	110 (62.5)	1221 (53.3)	0.02
Age in years, mean (SD)*	32.7 (18.4)	37.5 (19.7)	32.4 (18.2)	0.0004
Duration of the operation $>T$, N (%)*†	575 (23.3)	79 (44.9)	496 (21.6)	<0.0001
>1 procedure during the operation, N (%)	42 (1.7)	2 (1.1)	40 (1.8)	0.77
Re-intervention ≤1 mo for a noninfectious complication, N (%)	27 (1.1)	8 (4.6)	19 (0.8)	0.0004
Delay from admission to operation in days, mean (SD)	0.50 (7.4)	0.36 (0.69)	0.51 (7.67)	0.75
Emergency procedure, N (%)	2316 (93.8)	164 (93.2)	2152 (93.4)	0.63
Antibiotics before incision, N (%)	1468 (59.5)	106 (60.2)	1362 (59.4)	0.87
Laparoscopic technique, N (%)	1051 (42.6)	59 (33.5)	992 (43.3)	0.01
SSI by ASA score, N/total (%)				0.05
1		85/1238 (6.9)		
2		68/1087 (6.3)		
3		23/132 (17.4)		
4		0/11 (0)		
5		0/0 (0)		
SSI by contamination class*, N/total (%)				<0.0001
I		0/0 (0)		
II		23/689 (3.3)		
III		44/1100 (4.0)		
IV		109/679 (16.1)		
SSI by hospital, N/total (%)				0.12
A		21/312 (6.7)		
B		22/236 (9.3)		
C		13/190 (6.8)		
D		14/226 (6.2)		
E		27/293 (9.2)		
F		49/887 (5.5)		
G		24/228 (10.5)		
H		6/96 (6.3)		

*Risk factors with statistically significant differences between patients who underwent laparoscopic approaches and those operated using open surgery. The former were less often males (40% vs. 65%), were older (mean age = 33.7 vs. 32.1 yr), had longer interventions ($>T$ in 32% vs. 17%), and less class IV interventions (25% vs. 29%).
†T = 1 h.

by laparoscopy versus 1319/1416 (93.2%) of those done by open surgery ($P = 0.81$). These proportions were 2547/2652 (96.0%) versus 428/444 (96.4%) for cholecystectomy ($P = 0.79$), and 305/311 (98.1%) versus 1704/1781 (95.7%) for colon surgery ($P = 0.06$).

SSI rates in laparoscopic and open interventions were respectively 59/1051 (5.6%) versus 117/1417 (8.3%) for appendectomy ($P = 0.01$), 46/2652 (1.7%) versus 35/444 (7.9%) for cholecystecomy ($P < 0.0001$), and 35/311 (11.3%) versus 400/1781 (22.5%) for colon surgery ($P < 0.0001$). Figures for incisional SSI rates were 22/1051 (2.1%) versus 82/1417 (5.8) in appendectomy ($P < 0.0001$), 34/2652 (1.3%) versus 25/444 (5.6%) in cholecystectomy ($P < 0.0001$), and 15/311 (4.8%) versus 281/1781 (15.8%) in colon surgery ($P < 0.0001$). Organ/space SSI were also less frequent in laparoscopic than in open cholecystectomy: 12/2652 (0.5%) versus 10/444 (2.3%), $P = 0.0004$. But the rates of organ/space SSI did not differ significantly between laparoscopic and open appendectomy or colon surgery: 37/1051 (3.5%) versus 35/1417 (2.5%), $P = 0.15$, and 20/311 (6.4%) versus 119/1781 (6.7%), $P = 1.0$, respectively.

Characteristics of the patients and interventions, and the results of the univariate analysis of risk factors for SSI are presented in Tables 1–3. Despite differences in risk factors for SSI between patients who underwent laparoscopic interventions and those operated using open surgery, laparoscopic interventions were associated with a lower risk of SSI in the 3 studied operations, independently of other factors such as the ASA score, the contamination class, the duration of the operation, antibiotic prophylaxis, or others (Tables 4–6). When only incisional SSI was considered, laparoscopy remained an independent protective factor in multivariate analyses addressing appendectomy, cholecystectomy, and colon surgery: OR = 0.32 (CI 95% 0.19–0.53), 0.26 (0.15–0.46), and 0.31 (0.18–0.53), respectively. In contrast, laparoscopy was not retained in multivariate models developed to detect factors independently associated with organ/space SSI in none of the 3 studied interventions.

TABLE 2. Cholecystectomy: Characteristics of Patients and Surgical Interventions, Risk Factors for SSI (Univariate Analysis)

	Total (n = 3096)	SSI (n = 81)	No SSI (n = 3015)	*P*
Male gender, N (%)	1092 (35.3)	35 (43.0)	1057 (35.0)	0.16
Age in years, mean (SD)*	55.3 (17.0)	59.6 (19.9)	55.2 (17.0)	0.02
Duration of the operation $>T$, N (%)*†	327 (10.6)	16 (19.8)	311 (10.3)	0.02
>1 procedure during the operation, N (%)	186 (6.0)	9 (11.1)	177 (5.9)	0.06
Reintervention ≤1 mo for a noninfectious complication, N (%)	43 (1.4)	5 (6.2)	38 (1.3)	0.005
Delay from admission to operation in days, mean (SD)	1.7 (3.3)	2.2 (5.1)	1.7 (3.3)	0.15
Emergency procedure, N (%)	498 (16.1)	18 (22.2)	480 (15.9)	0.13
Antibiotics before incision, N (%)	1528 (49.4)	35 (43.2)	1493 (49.5)	0.31
Laparoscopic technique, N (%)	2652 (85.7)	46 (56.8)	2606 (86.4)	<0.0001
SSI by ASA score, N/total (%)*				0.0001
1		12/731 (1.6)		
2		35/1862 (1.9)		
3		30/459 (6.5)		
4		4/44 (9.1)		
5		0/0		<0.0001
SSI by contamination class, N/total (%)*				
I		0/0		
II		51/2312 (2.2)		
III		16/641 (2.5)		
IV		14/143 (9.8)		
SSI by hospital, N/total (%)				0.2
A		8/409 (2.0)		
B		7/341 (2.1)		
C		10/343 (2.9)		
D		13/254 (5.1)		
E		8/348 (2.3)		
F		27/950 (2.8)		
G		7/318 (2.2)		
H		1/133 (0.8)		

*Risk factors with statistically significant differences between patients who underwent laparoscopic approaches and those operated using open surgery. The former were younger (mean age = 53.7 vs. 65.2 yr), had shorter interventions ($>T$ in 8% vs. 24%), less ASA scores ≥3 (13% vs. 38%), and less class IV interventions (3% vs. 15%).

†$T = 2$ h.

TABLE 3. Colon Surgery: Characteristics of Patients and Surgical Interventions, Risk Factors for SSI (Univariate Analysis)

	Total (n = 2092)	SSI (n = 435)	No SSI (n = 1657)	*P*
Male gender, N (%)	1032 (49.3)	236 (54.3)	796 (48.0)	0.02
Age in years, mean (SD)*	65.3 (14.9)	65.8 (14.0)	65.2 (15.1)	0.46
Duration of the operation >*T*, N (%)*†	723 (34.6)	174 (40.0)	549 (33.1)	0.008
>1 procedure during the operation, N (%)	549 (26.2)	127 (29.2)	422 (25.5)	0.13
Re-intervention ≤1 mo for a non-infectious complication, N (%)	95 (4.5)	33 (7.6)	62 (3.7)	0.001
Delay from admission to operation in days, mean (SD)	3.3 (9.9)	3.1 (6.7)	3.3 (10.7)	0.06
Emergency procedure, N (%)*	438 (20.9)	129 (29.7)	309 (18.7)	<0.0001
Antibiotics before incision, N (%)	1589 (76.0)	320 (73.6)	1270 (76.6)	0.19
Laparoscopic technique, N (%)	311 (14.9)	35 (8.1)	276 (16.7)	<0.0001
SSI by ASA score, N/total (%)*				0.0002
1		35/255 (13.7)		
2		211/1058 (19.9)		
3		157/657 (23.9)		
4		31/120 (25.8)		
5		1/2 (50.0)		
SSI by contamination class, N/total (%)*				<0.0001
I		0/0 (0)		
II		267/1534 (17.5)		
III		47/183 (25.7)		
IV		120/375 (32.0)		
SSI by hospital, N/total (%)				<0.0001
A		30/179 (16.8)		
B		34/128 (26.6)		
C		37/226 (16.4)		
D		19/114 (16.7)		
E		24/158 (15.2)		
F		219/947 (23.1)		
G		67/243 (27.6)		
H		5/97 (5.2)		

*Risk factors with statistically significant differences between patients who underwent laparoscopic approaches and those operated using open surgery. The former were younger (mean age = 58.3 vs. 66.5 yr), had longer interventions (>*T* in 55% vs. 31%), less emergency procedures (6% vs. 23%), less ASA scores ≥3 (14% vs. 42%), and less class IV interventions (9% vs. 19%).
†*T* = 3 h.

TABLE 4. Multivariate Analysis of Risk Factors for SSI After Appendectomy

Variable	OR (CI 95%)	*P*
Duration of the operation >T*	2.51 (1.76–3.60)	<0.0001
Reintervention ≤1 mo for a noninfectious complication	3.89 (1.56–9.69)	0.004
Contamination class	2.38 (1.85–3.06)	<0.0001
Hospital B†	1.92 (1.16–3.18)	0.01
Hospital E†	1.76 (1.09–2.84)	0.02
Hospital G†	1.66 (1.02–2.70)	0.04
Laparoscopic technique	0.61 (0.43–0.87)	0.006

**T* = 2 h.
†Reference = hospital F.

TABLE 5. Multivariate Analysis of Risk Factors for SSI After Cholecystectomy

Variable	OR (CI 95%)	*P*
Reintervention ≤1 mo for a noninfectious complication	4.20 (1.51–11.7)	0.006
ASA score	1.63 (1.18–2.26)	0.003
Hospital D*	2.01 (1.08–3.75)	0.027
Laparoscopic technique	0.27 (0.16–0.43)	<0.0001

*Reference = hospital F.

Additional analyses on antibiotic prophylaxis showed that it was evenly administered in laparoscopic and open appendectomy (59% vs. 60%, $P = 0.68$), less frequently administered in laparoscopic than open cholecystectomy (48% vs. 58%, $P < 0.0001$), and more often administered in laparoscopic than open colon surgery (86% vs. 74%, $P < 0.0001$). Antibiotic prophylaxis varied also between hospitals from 46% to 81% in appendectomy ($P < 0.0001$) and from 63% to 89% in colon surgery ($P < 0.0001$). The hospitals positively associated with SSI in multivariate analyses were nevertheless not the ones with the lowest proportions of patients receiving antibiotic prophylaxis (B = 56%, E =

TABLE 6. Multivariate Analysis of Risk Factors for SSI After Colon Surgery

Variable	OR (CI 95%)	P
Duration of the operation >T*	1.39 (1.11–1.76)	0.005
Reintervention ≤1 mo for a non-infectious complication	2.27 (1.42–3.60)	0.0005
Contamination class	1.50 (1.31–1.70)	<0.0001
ASA score	1.17 (1.01–1.36)	0.04
Male gender	1.26 (1.02–1.57)	0.04
Hospital E†	0.61 (0.38–0.96)	0.03
Hospital G†	1.50 (1.09–2.06)	0.01
Hospital H†	0.16 (0.06–0.40)	0.0001
Laparoscopic technique	0.43 (0.29–0.63)	<0.0001

*T = 3 h.
†Reference = hospital F.

81%, G = 69% in appendectomy, and G = 81% in colon surgery).

DISCUSSION

This observational study found statistically significant lower rates of SSI after laparoscopic surgical interventions when compared with open interventions in appendectomy, cholecystectomy, and colon surgery.

Although patients operated with a laparoscopic technique left the hospital earlier than the others, their follow-up at 1 month did not differ for appendectomies and cholecystectomies. It even tended to be better after laparoscopic than after open colon surgery. It was carefully and systematically conducted by independent infection control nurses and available for more than 90% of the patients who underwent appendectomy, and more than 95% of those who underwent cholecystectomy or colon surgery. Thus, in contrast to the study by Richards et al,[3] no underestimation of SSI due to a lack of follow-up in patients operated with a laparoscopic technique could explain the observed differences in SSI rates in the present study.

Moreover, the nested case-control design used to confirm the protective effect of laparoscope for SSI revealed that the laparoscopic approach remained significantly associated with a lower risk of SSI after adjusting for potential confounding factors in multivariate analyses that included not only the components of the NNIS index, but also variables such as the patients' age and gender, the delay from their admission to operation, emergency operations, antibiotic prophylaxis, reoperations for a noninfectious complication, and the hospital in which the intervention took place.

Antibiotic prophylaxis should be administered before incision in every appendectomy and operation on the colon but is recommended only for high-risk situations in cholecystectomy.[8] The proportions of patients who had received antibiotics before incision in this study were found insufficient in appendectomy (59.5%) and colon surgery (76%). These low unsatisfying figures could be due to difficulties in data collection linked to the absence of a computerized prescribing system in most of the participating hospitals, to delayed or early administration of antibiotics that were not considered as a prophylaxis and thus not entered in case report forms, or to the absence of their administration. Antibiotic prophylaxis significantly varied between hospitals, but hospitals associated with higher risks of SSI were not those with the lowest proportion of patients receiving it. Antibiotic prophylaxis did not differ between laparoscopic and open appendectomy and was less administered in laparoscopic than open cholecystectomy, thus not contributing to any overestimation of the protective effect of laparoscopy in these interventions. It was more often administered in laparoscopic than open colon surgery but was surprisingly not significantly associated with SSI, neither in univariate nor multivariate analyses, thus probably not contributing to any confounding of the effect of laparoscopy on SSI.

Appendectomy is by definition an emergency procedure but, because of patients not operated on the day of their admission, was recorded as such in 93.8% of cases only. In any case, emergency interventions were associated with SSI in colon surgery only, and in univariate but not in multivariate analysis. This could be due to the fact that emergency was taken into account in multivariate models through high contamination classes that included perforated or abscessed acute sigmoiditis.

It is worth noting that, in appendectomy and colon surgery, most of the differences in SSI rates observed in our study between laparoscopic or open interventions were due to lower rates of incisional, but not intraperitoneal (organ/space) infections, whereas both incisional and organ/space infections were less frequent in laparoscopic cholecystectomy. However, in multivariate analyses adjusting for confounding factors, laparoscope use remained an independent protective factor only for incisional SSI, in cholecystectomy too. In contrast to the study by Biscione et al,[9] who found that laparoscopy was associated with a lower risk of incisional and organ/space infections, our findings suggest that, among the various existing theories on the protective effect of laparoscopy, the smaller incision leading to a reduced exposure of the abdominal wall plays a more important role than the preservation of the immune function and the reduction of the inflammatory response to tissue injury that have been found in experimental studies.[10,11] Boni et al[12] found even in their review that, although associated with lower rates of SSI, laparoscopic surgery seemed characterized by a higher incidence of postoperative intra-abdominal abscesses.

Interestingly, apart from undergoing a laparoscopic operation or a reintervention for a noninfectious complication, factors independently associated with SSI in multivariate analyses differed between the interventions. For example, all the 3 components of the NNIS index (contamination class, duration of the operation, and ASA score) were associated with SSI in colon surgery, whereas the ASA score did not predict SSI in appendectomy, neither did contamination class or the duration of the operation in cholecystectomy. In addition, the gender seemed to matter only in colon surgery and no hospital was systematically associated with higher or lower rates of SSI. This illustrates the difficulty to apply the 1991 NNIS basic risk index to all kinds of surgical procedures, trying to adjust for factors linked to the patient or the procedure itself, but not to quality of care, while comparing hospitals or surgeons between them. As stated by Gaynes et al,[2] there is still room for improvement in risk indexes. For instance, procedure specific risk indexes have been proposed in coronary artery bypass graft surgery and knee arthroplasty,[13–15] and, because it was associated with lower rates of SSI, the use of a laparoscope has recently been identified in the NNIS system as a factor that should modify the basic 1991 risk index in cholecystectomy, colon surgery, appendectomy, and gastric surgery.[2]

This difficulty to perform the right adjustment for case-mix when comparing SSI rates also constitutes a limitation of the present study. Indeed, despite our use of multivariate logistic regressions, considered a better method than matching in case–control studies,[16] the available candidate covariates put into the models may well not have captured all potential confounding factors. The male gender detected as a risk factor for SSI in colon surgery might for instance be confounded by the presence of colon cancer, more frequent in men. Furthermore, since this study was observational and the decision of surgeons to use a laparoscopic or an open approach was not random, unknown confounding factors may have been unbalanced between patients who underwent laparoscopic interventions and those who had open surgery. For example, obesity, cancer, or the lack of training could have influenced the surgeons' choice toward open surgery and could be factors independently associated with SSI. However, such selection biases were probably less prominent in appendectomy and cholecystectomy than in colon surgery. Finally, the lack of information on conversions from laparoscopic to open surgery during the intervention hindered an intention-to-treat analysis and might have contributed to an overestimation of the protective effect of laparoscopy. But conversion rates have been shown by others to be quite low in laparoscopic digestive surgery. They were 3% to 4% in cholecystectomy,[17] 7% to 12% in appendectomy,[18,19] and 10% in colon surgery.[20] It is thus unlikely that an intention-to-treat analysis would have significantly change the results of the present study.

In conclusion, among other advantages, the laparoscopic approach in appendectomy, cholecystectomy, and colon surgery seems to lower the risk of SSI when compared with open surgery. When feasible, this minimal invasive technique should thus be preferred to open surgery.

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