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ORIGINAL ARTICLE

Impact of tutorial assistance in laparoscopic sigmoidectomy for acute recurrent diverticulitis

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Abstract
Purpose Adequate training and close supervision by an experienced surgeon are crucial to assure the patient safety during laparoscopic training. This study evaluated the impact of tutorial assistance on the duration of surgery and postoperative complications after laparoscopic sigmoidectomy.
Methods The data from 235 patients undergoing laparoscopic sigmoidectomy were collected. Operating surgeons were classified as either residents/registrars (group A, tutorial assistance) or consultants operating autonomously (group B). Groups were compared concerning the duration of surgery and in-hospital complications using a multivariable regression model accounting for the most relevant confounders.
Results The median duration of the operation in group A ($n = 75$) was 221 min, and that in group B ($n = 160$) 189 min ($p < 0.001$). The risk of developing any in-hospital complication (Clavien–Dindo classification I–V) was 36.0 % in Group A and 32.5 % in group B (95 % CI −16.6, 9.6 %). The risk of developing moderate to severe surgical complications (Clavien–Dindo classification II-V) was 16.0 % in group A and 12.5 % in group B (95 % CI −13.3, 6.3 %).
Conclusions We were unable to demonstrate a clear impact of tutorial assistance on the risk of postoperative complications. Although associated with a longer duration of surgery, laparoscopic sigmoidectomy for acute recurrent sigmoid diverticulitis conducted by a junior supervised surgeon appears to be a safe surgical modality.

Keywords Laparoscopy · Surgical education · Experience · Sigmoidectomy · Diverticulitis

Purpose

Laparoscopic colorectal surgery has been shown to be safe and advantageous compared to conventional laparotomy concerning the outcome and morbidity [1–3]. Nevertheless, the technical requirements and the complexity of such minimally invasive surgery are still one of the major challenges in surgical residents' training [4, 5]. There is a need for structured training curricula and close supervision of interventions by experienced surgeons, especially for advanced laparoscopic procedures, such as laparoscopic sigmoidectomy for acute recurrent diverticulitis, where complex anatomy and inflammatory tissue alterations are highly expected.

Several studies have investigated the outcomes after surgery performed by residents compared to experienced surgeons [6–13]. Resident training is mainly conducted in high volume teaching hospitals, which show higher overall complication rates and morbidity due to the higher numbers of emergency operations and more complex disease patterns [14]. Teaching operations show a trend towards longer operation times, whereas similar overall

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postoperative complication rates compared to experienced surgeons have been found [7–9]. A recent analysis of the National Surgical Quality Improvement Program database from the American College of Surgeons, which included 60,711 patients, stated that resident participation in surgery is safe. Only prolongation of the operation time, and therefore increased mild surgical complications, mainly superficial surgical site infections (SSI), occurred [15]. Other studies showed increased lengths of the operation as one of the main conditions in teaching operations that does not appear to affect the outcome of colonic surgery [16], and is a poor indicator to classify the learning curve of a trainee surgeon [17]. In fact, surgical residents can perform simple laparoscopic procedures (e.g., appendectomy, cholecystectomy) safely without increased morbidity or complications [8, 9]. However, these findings are challenged by the fact that some studies suggest that higher levels of trainee experience [10] or having attained board certification [13] may be associated with more favorable outcomes after surgery.

The transition into levels of higher experience in laparoscopic surgery is still challenging. Thus, in complex laparoscopic surgery, the relevance of gaining a certain level of proficiency remains a problem [5, 18–20]. Furthermore, the term "experience" is inconsistently used in the literature to stratify the level of experience of the participating surgeons, which impairs comparisons among studies. Some authors define "experience" as having passed a certain training program [10], while others are referring to the number of years since board certification [13] or the number of operations performed [12], to classify the surgeons as "experienced". Additionally, the effect of caseload per time (surgeon and hospital volume) and of specialization on the outcome has been investigated, referring in general to the time after completion of training programs [6].

One way to compare outcomes according to different levels of experience is to compare tutorial assistance surgery to autonomously performed surgery [21]. Tutorial assistance is given when surgeons of different levels of seniority operate together, mainly conducted by the less experienced surgeon and supervised by the more experienced one.

There are basic and advanced laparoscopic procedures. According to the position statement by the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) [22], which was initially published in 1998 and was revised in 2003 and 2010, basic laparoscopic surgery comprises diagnostic laparoscopy, laparoscopic cholecystectomy and laparoscopic appendectomy. Advanced laparoscopic procedures are defined by SAGES as all other laparoscopic operations, including small and large bowel procedures. While basic laparoscopic procedures have been shown to be safely performed by residents, there is a lack of data regarding the impact of surgical experience on the outcome after surgery for advanced laparoscopic procedures using a validated classification of surgical complications.

Laparoscopic resection of the sigmoid colon due to recurrent diverticulitis with its intra-abdominal adhesions and occasional residual inflammatory tissue requires distinctive, well-trained surgical skills, indicating that this operation is an advanced laparoscopic procedure. Only a few studies investigated the impact of surgeon experience on the outcome after advanced laparoscopic surgery, with controversial findings [11, 13, 23].

This study aimed to assess the impact of tutorial assistance on the duration of surgery and postoperative complications while correcting for the most important confounders during an advanced laparoscopic procedure.

Materials and methods

The data from 237 patients who underwent laparoscopic colonic resection for acute recurrent diverticulitis were retrospectively gathered from January 1, 2005 to December 31, 2009. This study is a secondary analysis of a recently published analysis comparing early versus late surgery in patients with acute recurrent diverticulitis [24] and was approved by the local ethics committee as required for retrospective studies (EKBB, Ref-no. 101/10). Patients older than 18 years with acute recurrent colonic diverticulitis without free perforation upon initial presentation, and who underwent laparoscopic sigmoid resection, were included. Patients treated without surgery, patients with free perforated diverticulitis and patients treated by primary laparotomy because of multiple prior abdominal interventions ($n = 38$) were excluded. Recurrent diverticulitis was defined as a minimum of two recorded attacks, not counting unrecorded previous abdominal symptoms described by the patient and probably corresponding to mild diverticulitis. The diagnosis of acute recurrent diverticulitis was based on the patient history, the findings of physical examinations and actual or precedent computed tomography.

For the purpose of testing the actual hypothesis, one patient with right colon diverticulitis treated with ileocecal resection was excluded, as was one patient with missing information about the experience of the operating surgeon. The remaining 235 patients who underwent laparoscopic sigmoid resection were included in the analysis.

All patients underwent surgery in two Swiss teaching institutions for general and laparoscopic surgery: the University Hospital of Basel and the Cantonal Hospital of Bruderholz. All patients initially received antibiotic

treatment with either amoxicillin/clavulanic acid, tazobactam/piperacillin or ciprofloxacin/metronidazole. Depending on the patients' condition and the results of the clinical examination, the patients where surgically treated via early elective versus late surgery, as reported previously [24].

Surgical technique used for laparoscopic sigmoidectomy

Laparoscopic sigmoidectomy was performed according to the surgical standards in the participating hospitals. We used four to five trocars in a standardized position (Fig. 1). The mobilization of the sigmoid was performed from medial to lateral. The inferior mesenteric artery (IMA) was identified and devised as being either above the level of the left colonic artery (LCA) or the rectal superior artery (RSA)/sigmoid artery branch (SAB), depending on the extent of the diverticular disease. After division of the distal sigmoid site with stapler devices, the sigmoid colon was externalized via a suprapubic incision until a healthy segment was reached. The proximal colon dissection was performed with a scalpel over a purse string device. The circular stapler anvil was inserted, and the colon was closed with purse string sutures. The anastomosis was finalized laparoscopically with the circular stapler introduced via the rectum.

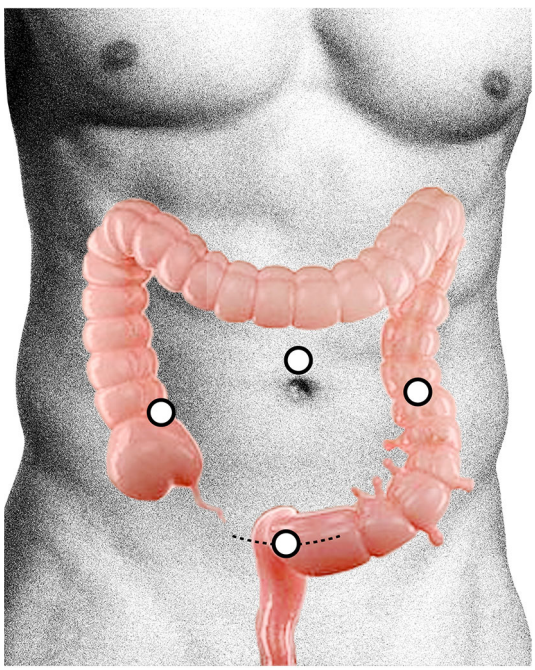

Fig. 1 Standardized trocar position for laparoscopic sigmoid resection

Definition of surgical experience

The operating surgeons were divided into two groups: residents/junior registrars, supervised by a consultant or senior registrar (group A, tutorial assistance) and consultants, operating autonomously (group B). Supervision consisted of a consultant or senior registrar being involved as surgical assistant during the entire procedure, leading the operating surgeon through the procedure. Considering that the nomenclature and surgical education programs of the British and American systems are not comparable to those of several other countries, we characterized groups A and B as following: junior registrars/residents were defined as surgeons who had previously conducted an appropriate number of basic laparoscopic procedures such as appendectomies and cholecystectomies and advanced open colorectal procedures. Consultants and senior registrars were defined as surgeons with board certification in general surgery, for which a minimum 6-year surgical expertise in general and laparoscopic surgery, including a defined number of interventions, is required, and with additional experience in advanced laparoscopic procedures.

Outcomes

Groups A and B were compared concerning the duration of surgery (measuring the time from skin incision to the end of skin closure/the time of adding wound dressings) as the primary outcome and in-hospital complications according to the Clavien–Dindo classification (grade 0–V) [25, 26].

Data collection

The baseline characteristics and information on the procedure and postoperative course were retrieved from the patients' charts. Whereas the diagnosis of acute diverticulitis was based on the patient history and clinical parameters on admission, Hinchey staging [27, 28] was undertaken based on the intraoperative findings, resulting in a Hinchey 0 classification in patients with a complete response to antibiotic treatment. Data were handled anonymously.

Statistical analyses

The length of the operation (log-transformed) was modeled in a linear regression analysis comparing residents/junior registrars versus consultants/senior registrars adjusted for the most important confounders: age per decade increase, gender, BMI per 1 unit increase, previous intra-abdominal vs. none/previous extra-abdominal surgery, Hinchey categories per 1 class increase and preoperative CRP per 10 units increase. The coefficients included in this model were back-transformed to obtain easily interpretable results, i.e.,

a percentage increase/decrease in the length of the operation per 1 unit increase of the corresponding covariate.

Furthermore, we calculated a risk difference with its 95 % confidence interval (CI) for any complication classified according to the Clavien–Dindo classification (i.e., stages I–V) between the experience levels (group B vs. group A). The same analysis was repeated for the risk of moderate to severe postoperative complications (i.e., Clavien–Dindo stage II-V).

The effects of experience on any postoperative complication (Clavien–Dindo I–V vs. 0) were analyzed with a logistic model adjusted for the most important confounders, including the severity of disease, early versus late surgery, age, BMI, ASA classification and duration of surgery, as reported previously [24]. The statistical analysis was performed using the Intercooled Stata Version 11.0 software program for Macintosh (StataCorp, College Station, Texas).

Results

Patient characteristics

Out of the 235 patients, 75 (32 %) underwent laparoscopic sigmoid resection by a resident/junior registrar supervised by either a consultant ($n = 59$) or a senior registrar ($n = 16$) (group A), while 160 sigmoid resections (68 %) were autonomously performed by consultants (group B, Table 1). The baseline characteristics were comparable in both groups: fifty-two percent of all patients ($n = 123$) were male, with no clear predominance in one of the two groups. The mean age of the patients was 60 years (SD 13) and the mean BMI was 28 kg/m^2 (SD 4.5). Most patients met the ASA II classification (63 %). Forty-one percent of patients had undergone a previous intra-abdominal surgery. Thirty-three percent of patients in group A and 46 % in group B had experienced more than two previous episodes

Table 1 Baseline characteristics

Variable	All ($n = 235$)	Group A tutorial assistance ($n = 75$, 32 %)	Group B consultant ($n = 160$, 68 %)
Gender of patient			
Female	112 (48 %)	33 (44 %)	79 (49 %)
Age, mean (SD)	60 (13)	60 (14)	60 (13)
Comorbidities			
BMI in kg/m^2, mean (SD)	28 (4.5)	28 (4.2)	28 (4.7)
Hypertension, *n* (%)	95 (40 %)	32 (43 %)	63 (39 %)
Chronic heart disease, *n* (%)	26 (11 %)	10 (13 %)	16 (10 %)
History of acute myocardial infarction (AMI), *n* (%)	6 (3 %)	1 (1 %)	5 (3 %)
Chronic heart failure, *n* (%)	10 (4 %)	6 (8 %)	4 (3 %)
COPD, *n* (%)	16 (7 %)	5 (7 %)	11 (7 %)
Diabetes mellitus, *n* (%)	13 (6 %)	4 (5 %)	9 (6 %)
History of malignancy, *n* (%)	10 (4 %)	5 (7 %)	5 (3 %)
Current immunosuppression, *n* (%)	5 (2 %)	2 (3 %)	3 (2 %)
ASA classification			
I, *n* (%)	31 (13 %)	12 (16 %)	19 (12 %)
II, *n* (%)	149 (63 %)	47 (63 %)	102 (64 %)
III, *n* (%)	55 (23 %)	16 (21 %)	39 (24 %)
Previous intra-abdominal operation(s), *n* (%)	96 (41 %)	31 (41 %)	65 (41 %)
Preoperative inflammatory markers			
Preoperative CRP level* in mg/l, median (IQR)	5.0 (5.0–15)	5.1 (4.9–18)	5.0 (5.0–14)
Preoperative LC × 10e 9/l*, median (IQR)	7.2 (6.0–8.9)	7.4 (6.5–9.1)	7.0 (5.9–8.9)
Previous recorded diverticulitis episodes			
0–2, *n* (%)	137 (58 %)	50 (67 %)	87 (54 %)
≥3, *n* (%)	98 (42 %)	25 (33 %)	73 (46 %)
CT-guided drainage, *n* (%)	9 (4 %)	–	9 (6 %)

One patient with ileocecal resection and one patient with a missing experience level were excluded from the analysis

* One value missing

of diverticulitis, which were recorded in their medical files. Preoperative interventional CT-guided drainage was performed in 4 % ($n = 9$) of the patients in group B, and none in group A. The preoperative inflammatory laboratory marker levels were found to be normal in both groups.

Procedure characteristics

As presented in Table 2, the median duration of surgery was 221 min in group A (interquartile range, IQR 180–267) and 189 min in group B (IQR 165–231). The majority of patients were intraoperatively assessed as being Hinchey 0 (diverticulosis only) in both groups. Conversion to open surgery was necessary in 3 % ($n = 2$) of the patients in group A and in 6 % ($n = 10$) in group B.

In the univariate and multivariable log-linear regression analysis corrected for the most important confounders, the difference between both groups concerning the duration of surgery was significant (Table 3). In the multivariable analysis, group B presented a 13 % shorter median length of the operation (e^{β} 0.87, 95 % CI 0.82, 0.93, $p < 0.001$) compared to group A. Female gender of the patient was associated with a 9 % shorter duration of surgery (e^{β} 0.91, 95 % CI 0.86, 0.98, $p = 0.007$), compared to male gender. Furthermore, a Hinchey-stage increase by one class (e^{β} 1.08, 95 % CI 1.02, 1.14) and a BMI increase by one unit (e^{β} 1.01, 95 % CI 1.00, 1.02) were significantly associated with a longer duration of surgery. There was insufficient evidence regarding whether the patient age, previous intra-abdominal surgery, time point of surgery (late vs. early elective) and levels of preoperative inflammatory markers (CRP) had any impact on the duration of the surgery.

Table 2 Procedure-related characteristics

	All ($n = 235$)	Group A tutorial assistance ($n = 75$, 32 %)	Group B consultant ($n = 160$, 68 %)
Hinchey stage (assessed intraoperatively)			
0, *n* (%)	175 (74 %)	55 (73 %)	120 (75 %)
I, *n* (%)	21 (9 %)	8 (11 %)	13 (8 %)
IIa, *n* (%)	37 (16 %)	11 (15 %)	26 (16 %)
IIb, *n* (%)	2 (1 %)	1 (1 %)	1 (1 %)
Conversion to laparotomy, *n* (%)	12 (5 %)	2 (3 %)	10 (6 %)
Reason for conversion			
Anatomy, *n* (%)	4 (2 %)	–	4 (3 %)
Adhesions, *n* (%)	8 (3 %)	2 (3 %)	6 (4 %)
Duration of operation in minutes, median (IQR)	200 (165–240)	221 (180–267)	189 (165–231)

Table 3 The results of the univariate and multivariate linear regression analysis for the log-transformed duration of the operation ($n = 234$ due to one missing preoperative CRP value)

Covariates	Univariate analysis		Multivariate analysis	
	e^{β} (95 % CI)*	*p* value	e^{β} (95 % CI)*	*p* value
Consultant vs. tutorial assistance	0.87 (0.81, 0.93)	<0.001	0.87 (0.82, 0.93)	<0.001
Age of patient (per decade)	1.00 (0.98, 1.03)	0.728	1.02 (1.00, 1.05)	0.058
Gender (female vs. male)	0.91 (0.85, 0.97)	0.003	0.91 (0.86, 0.98)	0.007
BMI (per 1 unit increase)	1.01 (1.00, 1.01)	0.049	1.01 (1.00, 1.02)	0.014
Previous intra-abdominal operation vs. none/extra-abdominal operation	0.95 (0.89, 1.01)	0.108	0.96 (0.90, 1.02)	0.183
Late vs. early operation	0.93 (0.87, 0.99)	0.029	1.03 (0.94, 1.12)	0.529
Hinchey stage (per 1 class increase)	1.08 (1.04, 1.13)	<0.001	1.08 (1.02, 1.14)	0.004
Preoperative CRP (per 10 unit increase)	1.01 (1.00, 1.02)	0.016	1.01 (1.00, 1.02)	0.241

* Exponentiated coefficients were given to make the interpretation easier, e.g., 0.87 became the factor by which the median length of the operation should be multiplied to compare operations performed by a consultant and with tutorial assistance, respectively. Operations performed by a consultant seemed to show a 13 % shorter duration of the operation compared to residents with tutorial assistance; on the other hand, 1.08 corresponds to an 8 % prolongation in the median length of the operation

In-hospital complications

As shown in Table 4, the risk of developing any in-hospital complications was 36.0 % in group A and 32.5 % in group B. The risk difference between the groups was −0.035 or −3.5 % (95 % CI −0.166, 0.096). On average, there was a 3.5 % lower risk of developing any in-hospital complication according to the Clavien–Dindo classification if a consultant performed the laparoscopic sigmoidectomy. However, due to the 95 % CI, the risk of developing any in-hospital complication could be up to 17 % higher or 10 % lower in group A compared to group B. The risk of developing moderate to severe surgical complications (Clavien–Dindo classification stages II–V) was 16 % in group A and 12.5 % in group B. On average, there were 3.5 % fewer severe in-hospital complications according to the Clavien–Dindo classification if a consultant (group B) performed the operation, but according to the 95 % CI, a 13 % higher or a 6 % lower risk of a severe in-hospital complications was also plausible.

A comparison of the incidences of surgical complications, broken down by the different types of complications, as well as the comparison of incidences of the overall postoperative complications (broken down by the Clavien–Dindo stages) are presented in Table 4.

Table 4 The surgical complications (several complications per patient possible), in-hospital complications according to the Clavien–Dindo classification (only the most severe was considered), the risk and risk difference

	All ($n = 235$)	Group A tutorial assistance ($n = 75$, 32 %)	Group B consultant ($n = 160$, 68 %)	Risk difference Group B vs. group A (point estimate and 95 % CI)
In-hospital complications				
None (stage 0), *n* (%)	156 (66 %)	48 (64 %)	108 (68 %)	–
Any (stages I–V), *n* (%)	79 (34 %)	27 (36 %)	52 (33 %)	–
Risk of any	0.336	0.360	0.325	−0.035 (95 % CI −0.166, 0.096)
None/mild (stages 0–I), *n* (%)	203 (86 %)	63 (84 %)	140 (88 %)	–
Moderate/severe (stages II–V), *n* (%)	32 (14 %)	12 (16 %)	20 (13 %)	–
Risk of moderate/severe (stages II–V)	0.136	0.160	0.125	−0.035 (95 % CI −0.133, 0.063)
All in-hospital complications stage, *n* (% of all)				
None	156 (66 %)	48 (64 %)	108 (68 %)	–
I	70 (30 %)	26 (35 %)	44 (28 %)	–
II	24 (10 %)	9 (12 %)	15 (9 %)	–
III	25 (11 %)	12 (16 %)	13 (8 %)	–
IV	3 (1 %)	–	3 (2 %)	–
V	1 (0 %)	–	1 (1 %)	–
Most severe in-hospital complication per patient stage, *n* (% of all)				
None	156 (66 %)	48 (64 %)	108 (68 %)	–
I	47 (20 %)	15 (20 %)	32 (20 %)	–
II	15 (6 %)	4 (5 %)	11 (7 %)	–
III	15 (6 %)	8 (11 %)	7 (4 %)	–
IV	1 (0 %)	–	1 (1 %)	–
V	1 (0 %)	–	1 (1 %)	–
Type of surgical complication, *n* (% of all)				
None	203 (86 %)	61 (81 %)	142 (89 %)	–
SSI	10 (4 %)	4 (5 %)	6 (4 %)	–
Intra-abdominal abscess	7 (3 %)	3 (4 %)	4 (3 %)	–
Anastomotic leak	13 (6 %)	7 (9 %)	6 (4 %)	–
Bleeding	6 (3 %)	4 (5 %)	2 (1 %)	–
Burst abdomen	1 (0 %)	–	1 (1 %)	–
Ileus	3 (1 %)	–	3 (2 %)	–
Others	4 (2 %)	2 (3 %)	2 (1 %)	–
Total complications	44 in 32 patients	20 in 14 patients	24 in 18 patients	–

The influence of tutorial assistance as a predictor of the occurrence of any in-hospital complications was ambiguous (univariate analysis: OR 0.87, 95 % CI 0.49, 1.55, $p = 0.645$; multivariable analysis: OR 0.75, 95 % CI 0.40, 1.40, $p = 0.366$) [24]. Additionally, in the multivariable analysis, neither early vs. late surgery, nor the severity of disease, BMI or duration of surgery were significant predictors of complications; the ASA was borderline significant (OR 1.68, 95 % CI 0.99, 2.84, $p = 0.056$) and age was a significant predictor (OR 1.27, 95 % CI 1.00, 1.60, $p = 0.048$), as reported previously [24].

Discussion

This cohort study shows that (1) the duration of laparoscopic sigmoidectomy is significantly prolonged in cases of tutorial assistance and (2) the risk of postoperative complications seems to be comparable regardless of tutorial assistance. Therefore, closely supervised surgical teaching in advanced laparoscopic surgery seems to be safe, but time-consuming.

The findings of our study emphasize the dilemma of surgical education, which consists of the need for active participation by the junior surgeon in theaters stressing hospital resources on one side, and the fear of increased complication rates during teaching procedures on the other side. Our findings show that, despite using healthcare resources, which was characterized by a prolonged operation time with its additional economic burden, involving consultants and senior registrar surgeons for supervision, showed no significant impairment of the surgical outcome in teaching surgery, even in complex cases.

The differences in the rates of postoperative complications in teaching operations have been controversially discussed in the literature [7–11, 13]; most studies failed to find an association between surgery by inexperienced surgeons and increased postoperative complications [7–9]. In a recent analysis, only minor surgical complications (superficial surgical site infections) were found to increase when junior surgeons participated in surgery [15]. Thus, the risk difference of 3.5 % between both groups in our results seems to be acceptable for performing a complex and challenging procedure such as laparoscopic sigmoidectomy for acute recurrent diverticulitis. However, given the large confidence interval rendering incidences of 10 % fewer complications or 16 % more complications comparing tutorial assistance to autonomous surgery, definitive conclusions cannot be drawn from this result. The increased duration of surgery in male patients with limited space in the pelvis, in patients with a higher BMI and in patients with a higher Hinchey stage is explained by the surgical challenge of these conditions and is an expected finding.

As shown in our recently published study based on the same database, the duration of surgery was not an independent predictor of in-hospital complications [24], which is supported by the findings of previous studies [14, 29, 30]. Based on the learning curve in laparoscopic colon surgery, the presented difference in the median duration of surgery between the two groups of 32 min may not be surprising, since the surgeons in group A had not yet completed their learning curve. Especially in complex surgeries, the step-by-step approach with time-consuming verbal instructions, discussion and assistance of the supervising surgeon may explain this increase in the length of the operation. Time-consuming but safe performance of advanced teaching surgery is more important than a short duration of surgery. Thus, tutorial assistance seems to be safe, and the small increase in operation time does not seem to increase the risk of an adverse outcome.

However, the economic impact of an increased duration of surgery may be significant. In an investigation including data from more than 9,000 laparoscopic cholecystectomies carried out in Switzerland, we found a median increase of 18 min when patients were operated on by residents compared to senior consultants, resulting in an incremental cost of €492 per operation [31]. Extrapolating the operating time minute costs of the cited study to our data based on an average currency exchange rate between 2005 and 2009 of our study period (€0.665 per CHF), the median difference between group A and group B of 32 min in the length of the operation resulted in a CHF 892.80 (€593) higher cost in cases of tutorial assistance in this study. Given the retrospective characteristics of the present study, a thorough economic analysis has not been carried out. However, such a study would need to include the costs of potential complications. Although the increased complications rate of 3.5 % in group A compared to group B did not reach significance, the potential for increased costs in group A due to complications cannot be excluded. Based on previous economic evaluations for anastomotic leaks in the UK [32] and for surgical site infections in our hospital [33], complications may lead to considerable additional costs, i.e., €12,724 per anastomotic leak and €16,039 per SSI. Thus, the impact of tutorial assistance on the economic burden needs further clarification based on prospective data. Coverage of these expenses related to training thus needs to be considered for reimbursement systems for public health care. This is of specific impact in the current situation of our country, where DRG-based (diagnosis-related groups) remuneration has recently been introduced.

It also needs to be kept in mind that the length of the operation may be of limited value to characterize the learning curve and experience of surgeons, since with increasing experience, more difficult cases will be

addressed laparoscopically, and thus, the length of the operation may remain high [17].

Surgical teaching has recently become an important issue in surgical research. External factors such as the implementation of a weekly work-hour restriction for residents, as well as economic, educational and ethical considerations have led to a decreased opportunity for learning in the operating room, and therefore, challenges in the quality of surgical education [34–36]. Furthermore, the complexity, diversity and technical advances of surgical approaches such as minimally invasive surgery, percutaneous interventions and endoscopic examinations, alter the experience of surgical residents [37]. Therefore, the implementation of structured surgical teaching, including technically highly demanding procedures, within the regulated working hour limitations are a challenge in daily surgical practice.

The learning curve for advanced laparoscopic procedures may be considerable, and has been estimated to be in a range of 20–60 procedures for laparoscopic colorectal surgery [38–40]. Colorectal surgical fellows' and laparoscopic fellows' experience tends to breach this threshold within their teaching period, but general surgical residents are at risk of lacking an appropriate number of laparoscopic colorectal operations [19]. Considering that training with experts improves the surgical results and postoperative complication rates in residents training [41], surgical training and education, especially in colorectal surgery, remains a permanent challenge in teaching institutions and hospitals.

Surgical residents with basic laparoscopic skills mainly perform advanced laparoscopic procedures with the assistance of an experienced consultant surgeon. Although this concept of teaching and learning in theaters seems to be safe, additional alternative training concepts should be implemented, such as structured debriefing after surgery and the use of simulated environments, e.g., virtual reality (VR) training.

To the best of our knowledge, this study is one of the biggest cohort studies that has investigated the impact of the surgical training environment on the length of the operation and complications in laparoscopic colon resection for a benign acute inflammatory disease as an example of an advanced laparoscopic procedure. Given the fact that there is a lack of prospective randomized data, this study contributes to answering the question whether surgical teaching is safe, even in complex laparoscopic surgery. While measuring the length of the operation is simple, reliable and widely used to investigate the experience in surgery; we also conducted our analysis using a validated classification system assessing surgical complications [25, 26]. Our data showed that this type of operation seems to be suitable as a teaching operation for advanced laparoscopic surgery; provided adequate supervision is given.

Keeping with the character of a retrospective study, there are some limitations to the present investigation. First, the data were gathered out of patient files and operating theater reports. Therefore, the selection of surgeons and a possible association between the surgeons' experience and the expected complexity of the operation cannot be excluded, which may bias our results and narrow the separation of the two groups. We accounted for this by correcting for the most relevant confounders in the multivariable analysis. Second, the information about the details of the supervising process during the operation was not available in the data set. Due to the retrospective nature of this study, gathering detailed information about the surgical experience of all participating surgeons in years and the number of performed sigmoidectomies at the time point of each procedure was thought to be unreliable. Moreover, the years of surgical training may not allow firm conclusions to be drawn about the experience of surgeons, especially in our setting, in which residents work in different wards, some of them (such as emergency room and intensive care unit) without performing any surgical procedures, while others work in surgical wards unrelated to general or visceral surgery. Therefore, the surgical experience could best be indicated by the level of seniority at the moment of the operation, which served as a surrogate for surgical experience. Additionally, although the number of observations seems to be adequate, the limited number of moderate to severe complications limited the power when investigating this outcome. Furthermore, the Swiss medical staff nomenclature is not comparable to the Anglo-American nomenclature. The terms "resident," "registrar" and "consultant" are not common cadre denominations in Switzerland and may differ from those in other European countries. We tried to relate the surgical experience of all performing surgeons in our database as near as possible to the Anglo-American education levels (senior house officer, resident, junior and senior registrar, consultant). However, this fact could lead to difficulty drawing direct comparisons between our present results and those of other studies.

At present, there still remain some unanswered questions. Surgical education, such as with VR training or structured debriefing, the limitation of risk factors in the operating theater and the availability of experienced instructors are key factors required for successful surgical training. Whereas the positive effect of VR training in developing basic surgical skills has been confirmed in a recent meta-analysis [42], the impact of VR training for complex laparoscopic surgery such as sigmoid colon resection has not yet been thoroughly investigated. This is mainly explained by the fact that complex abdominal procedures with numerous alterations of anatomical and intraoperative conditions are difficult to simulate, and simulation systems have only recently been developed. Therefore, most of the literature in

the field is currently based on more basic simulations. Furthermore, it remains unclear when a surgeon may be classified as "experienced", because this depends not only on the completion of training programs, the years of experience as a surgeon and the number of individual interventions conducted, but also on the specialization, surgeon and hospital volume [6]. A unique definition of surgical experience is therefore still lacking.

In conclusion, our present results support that junior surgeons in teaching hospitals, when supervised by consultants, can safely perform laparoscopic colonic surgery. The longer duration of surgery in cases of tutorial assistance is of significant economic impact that needs to be accounted for. Further research should address the impact of complex simulations on the performance of trainees during advanced laparoscopic procedures with the ultimate goal of enhancing patient safety.

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