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Surgical Treatment of Acute Recurrent Diverticulitis: Early Elective or Late Elective Surgery. An Analysis of 237 Patients

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Abstract
Background The optimal timing of elective surgery in diverticulitis remains unclear. We attempted to investigate early elective versus late elective laparoscopic surgery in acute recurrent diverticulitis in a retrospective study.
Method Data of patients undergoing elective laparoscopic surgery for diverticulitis were retrospectively gathered, including Hinchey stages I–II a/b. The primary endpoint was in-hospital complications according to the Clavien–Dindo classification. Secondary endpoints were surgical complications, operative time, conversion rate, and length of hospital stay.
Results Of 237 patients, 81 (34%) underwent early elective operation (group A) and 156 (66%) underwent late elective operation (group B). In-hospital complications developed in 32% in group A and in 34% in group B (risk difference 2%, 95% Confidence Interval (95% CI): −11%, 14%). Higher age ($p = 0.048$) and borderline higher American Society of Anesthesiologists score ($p = 0.056$) were risk factors for in-hospital complications. Severe surgical complications occurred in 9% of patients in group A and 10% in group B (risk difference 2%, 95% CI: −6%, 9%). Conversion rate was 9% in group A and 3% in group B ($p = 0.070$). Severity of disease did not seem to have an impact on complications or length of hospital stay. The median postoperative hospital stay was 8 days in both groups (interquartile range 6–10). Mean operative time was 220 min (SD 64) in group A and 202 min (SD 48) in group B.
Conclusions This is the first study comparing early versus late elective surgery for diverticulitis in terms of the postoperative outcome using a validated classification. Although the retrospective setting and large confidence intervals don't allow definitive recommendations, these results are of utmost importance for the design of future prospective, randomized controlled trials.

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Introduction

Diverticulosis is one of the most common benign colorectal disorders in the Western world, with a continuously increasing prevalence. About one-third of people over the age of 45 years and up to two-thirds of people over 85 years of age may be affected [1–3]. In over 90% of patients, the disease is located in the sigmoid colon [4]. Of the patients with sigmoid diverticular disease, 10–25% will develop diverticulitis and its complications [5, 6]. This is of enormous socioeconomic relevance, with approximately 200,000 hospital admissions per year in the United States [7]. The indication for surgery should be determined on a case-by-case basis according to the current recommendation of the Standards Committee of the American Society of Colon and Rectal Surgeons [8] (ASCRS), the Consensus Conferences of the Scientific Committee of the European Association for Endoscopic Surgery [9], and the stage of the disease [10]. Additionally, the risk of recurrence and developing complications should be individually assessed [10]. The ultimate goal of the surgical intervention is the removal of the disease with prevention of its recurrence and restoration of bowel continuity whenever possible [11]. Elective laparoscopic colectomy has become a standard procedure for symptomatic diverticular disease [11–16]. It can be safely performed even in complicated diverticulitis [17] and has a better outcome than laparotomy [18–20]. A recently published meta-analysis concerning laparoscopic surgery in diverticulitis showed less intraoperative blood loss, shorter hospital stay, reduced need of analgesia, earlier beginning of solid diet, and reduced morbidity and major complications compared to open surgery [21]. To date, published studies are still controversial concerning the ideal timing of the surgical intervention in acute diverticulitis [1, 2, 10, 12, 13, 16, 17, 22–35]. Based on the findings of Siewert et al. [27], early elective surgery has gained increasing interest, because it is associated with good outcome and low morbidity [19], and it significantly increases the patient's quality of life and social function [20, 36]. This early elective concept, based on adequate response to antibiotic therapy, tries to join the advantages of reduced tissue edema, avoided post-inflammatory adhesions, prevented recurrent diverticulitis, and single hospital stay. Only three retrospective studies and one prospective but not randomized study have compared the timing of elective surgery (early elective versus late elective surgery) in acute diverticulitis [1, 2, 17, 22]. The results of those studies remain controversial, especially concerning the important surgically related issues, such as complications and conversion rate.

In the present study we investigated whether early elective surgery, as compared to delayed surgery, in acute recurrent diverticulitis can be safely performed and without a higher risk of complications and conversion rate. Furthermore, we are the first to evaluate risk factors for any in-hospital complication according to the validated Clavien–Dindo classification [37–39] and for the length of the hospital stay.

Methods

Patients and clinical pathway

We retrospectively analyzed data from all consecutive patients who underwent laparoscopic colonic resection for acute recurrent diverticulitis between 1 January 2005 and 31 December 2009 in the University Hospital of Basel (Switzerland) and the Cantonal Hospital of Bruderholz (Switzerland). Both hospitals are teaching institutions for general and laparoscopic surgery, respectively.

Patients older than 18 years initially presenting with acute recurrent diverticulitis without free perforation were included in the study. All conservatively treated patients, patients with free perforated diverticulitis (Hinchey III–IV), and patients who underwent primary laparotomy ($n = 38$) instead of laparoscopy due to several previous abdominal operations were excluded. The Hinchey classification was considered, because the modified version has been recommended by the E.A.E.S. (European Association for Endoscopic Surgery) [9]. We defined recurrent diverticulitis as the previous occurrence of ≥ 2 recorded attacks. Diagnosis of acute recurrent diverticulitis was based on anamnesis, clinical examination, and computed tomography (CT) scans on admission or in previous admissions. We retrieved the numbers of previous attacks of diverticulitis and the findings on indication for surgery retrospectively from the patients' records. In certain cases, previous abdominal symptoms that would meet the criteria of mild recurrent diverticulitis had been described by the patients in their history but had not been recorded by their general practitioner or at the time of previous inpatient treatment. For the purposes of this study, those self-reports were not counted as episodes of diverticulitis in order to account for documented episodes only. We also noted that the description of intraoperative findings varied among the different surgeons. The severity of diverticulitis according to the Hinchey classification was determined not upon initial presentation, but at the time of surgery considering operation reports. Therefore, the patients included in the analysis present only Hinchey stages I–IIa/b. To compare preoperative and intraoperative findings with the actual severity of diverticulitis, we recorded the histopathological findings of the specimen. A number of patients initially presenting with acute diverticulitis and treated with an antibiotic regimen were intraoperatively found to present simple diverticulosis with no signs of inflammation and were classified as Hinchey 0.

We categorized early elective surgery (group A) as surgery within the same hospitalization and within 19 days of admission. Three patients whose hospital stay exceeded 19 days from admission to surgery (which was unrelated to the diverticulitis and was used to treat other leading comorbidities) were excluded from group A to preserve the meaning of early elective surgery. Late elective surgery (group B) was defined as surgery 6–8 weeks after admission for acute diverticulitis in a second hospital admission.

All patients received antibiotic therapy during the acute phase of diverticulitis (amoxicillin/clavulanic acid or tazobactam/piperacillin or ciprofloxacin/metronidazol). Considering that most guidelines recommend surgery after a second attack of diverticulitis (ACCRS, Consensus Conferences of the Scientific Committee of the European Association for Endoscopic Surgery), the decision for one of the two treatment strategies was taken case by case during admission and the initial treatment period, with respect to the individual patient's condition and subsequent clinical examinations. As far as possible in the retrospective setting, clinical response to the antibiotic therapy, course of inflammatory markers in the blood tests, and patients' social background could be found as the main decision criteria for performing either early elective surgery or late elective surgery. Whether clinical impairment instead of clinical improvement was the indication for surgery in group A could retrospectively not be assessed in all cases. Therefore, we accounted for a number of potential confounders in the analysis, including histological severity of the disease, to reduce selection bias in the process of surgical decision making and indications for surgery.

Neither the number of patients declining surgery nor the number of patients scheduled for late surgery who ultimately declined operative treatment could be retrospectively determined. No patients in group B were admitted for surgery earlier than scheduled.

This retrospective analysis was approved by the local ethics committee (EKBB, Ref-No. 101/10), as is a standard procedure for all studies carried out in our setting.

Data collection

Collected data were age, gender, co-morbidities (body mass index [BMI], hypertension, coronary heart disease, chronic obstructive pulmonary disease [COPD], diabetes, malignancy and American Society of Anaesthesiologists [ASA] score), previous intra- and extra-abdominal operations, leukocyte count and C-reactive protein (CRP) level, type of surgery, reasons for conversion, experience of the surgeons, and results of the histological assessment of the specimen (diverticulosis, simple diverticulitis, local mesenteric abscess, and locally contained perforation). Primary outcomes were in-hospital complications according to the Clavien–Dindo classification (grade 0–V) [37–39]. After the implementation of this classification in 1992 it was updated in 2004 [39], and in a subsequent five-year evaluation it was shown to be simple and reproducible with a low interobserver variability even in complex scenarios of complications [37]. If the patient had more than one complication, the worst was considered for the analysis. Secondary endpoints were severe surgical complications (defined as the following: intra-abdominal abscess including organ/space surgical site infection but excluding incisional surgical site infection (SSI) [40], anastomotic leak, intra-abdominal bleeding, burst abdomen, and postoperative ileus persisting longer than 3 days), duration of surgery, conversion rate, and length of hospital stay after surgery.

Statistical analysis

Data were handled anonymously. The statistical analysis was performed using Intercooled Stata Version 11.0 for Macintosh (StataCorp, College Station, TX). The effect of early elective versus late elective operation on any postoperative complication (Clavien–Dindo I–V versus 0) was analyzed with a logistic model adjusted for the most important confounders. These were the following: severity of disease (simple diverticulitis and locally contained perforation, each compared with diverticulosis), age per decade increase, BMI per 1 unit increase, experience of the surgeon (consultant/head of department versus registrar/senior house officer), ASA classification per 1 class increase, and duration of surgery per 10 min increase. A comparison of severe in-hospital complications (Clavien–Dindo II–V) versus minor or no complications (Clavien–Dindo 0–I) was omitted because of lack of power due to the small numbers of severe complications. The effect of early elective versus late elective surgery on the number of postoperative days until discharge was compared in a log-normal regression model adjusted for the same covariates. The coefficients of this model were back-transformed in order to get easily interpretable results, i.e., percentage increase in hospital days per one unit increase of the corresponding covariate. The risk of conversion in both groups was compared with a chi-squared test.

A threshold of acceptable difference in complication rates for group A compared to group B was a priori set in order to avoid data-driven interpretation of the results. Objectives of less than 10% difference for experiencing any (minor or major) in-hospital complication according to the Clavien–Dindo classification and less than 3% increase of surgical complications were defined. Therefore, we calculated the risk difference and its 95% CI: for both Clavien–Dindo classification grades I–V versus none and surgical complications versus none.

Results

Patient characteristics

The baseline characteristics of our cohort were comparable in both groups. Of the 237 patients studied (male = 123, 52%; female = 114, 48%), 81 (34%) underwent early elective surgery (group A) and 156 patients (66%) had late elective surgery (group B). Mean age was 60 years (SD 13).

Both groups showed heterogeneity in severity of diverticulitis at operation. As shown in Table 1, we found in group A Hinchey 0 in 33% ($n = 27$), Hinchey I in 25% ($n = 20$), Hinchey IIa in 41% ($n = 33$), and Hinchey IIb in 1% ($n = 1$). The main condition of patients in group B was diverticulosis only, defined as Hinchey 0 (96%, $n = 149$). Only a few had still ongoing inflammatory processes ($n = 7$).

Table 1 Baseline characteristics of the 237 patients in the study

Variable	All (n = 237)	Group A (n = 81)	Group B (n = 156)
Gender			
Male	123 (52%)	44 (54%)	79 (51%)
Female	114 (48%)	37 (46%)	77 (49%)
Age, mean (SD), years	60 (13)	59 (15)	60 (13)
ASA score			
I	32 (14%)	8 (10%)	24 (15%)
II	149 (63%)	50 (62%)	99 (63%)
III	56 (24%)	23 (28%)	33 (21%)
Previous surgery			
None/extra-abdominal	141 (59%)	52 (64%)	89 (57%)
Intra-abdominal	96 (41%)	29 (36%)	67 (43%)
Previous diverticulitis episodes			
0–2	138 (58%)	62 (77%)	76 (49%)
≥3	99 (42%)	19 (23%)	80 (51%)
CRP preoperative, median (IQR), mg/dl	5 (5.0–15)	18 (8.3–42)	5.0 (4.0–5.0)
Leucocytes preoperative, median (IQR) × 10^9	7.3 (6.1–8.9)	8.7 (6.4–11.2)	6.9 (6.0–8.1)
Hinchey stage			
0 (diverticulosis)	176 (74%)	27 (33%)	149 (96%)
I	22 (9%)	20 (25%)	2 (1%)
II a	37 (16%)	33 (41%)	4 (3%)
II b	2 (1%)	1 (1%)	1 (1%)
CT-guided percutaneous drainage	9 (4%)	9 (11%)	–

ASA American Society of Anesthesiologists; *CRP* c-reactive protein; *IQR* interquartile range; *CT* computed tomography

The results of the cross tabulation of the Hinchey classification and the histological findings are shown in Table 2. Of 176 patients assessed intraoperatively as Hinchey 0, only 55% (n = 97) showed diverticulosis in the histopathological findings. In 79 patients (45%), residual inflammatory changes were noted in the histopathology reports, including one locally contained perforation (1%), 13 mesenteric abscesses (7%), and 65 cases of simple diverticulitis (37%). Of the 22 cases of Hinchey I, 6 specimens showed higher degrees of inflammation (28%), and 14 patients had diverticulitis only (64%). The histopathology for patients with Hinchey IIa (n = 37) revealed diverticulitis, almost equal numbers of simple diverticulitis (I = 14, 38%), simple mesenteric abscess (n = 10, 27%), and locally contained perforation (n = 12, 32%).

Both groups differed with regard to the number of recorded previous attacks of acute diverticulitis. Twenty-three percent of patients in group A had suffered at least three attacks, whereas 51% of the patients in group B had experienced at least three attacks. The majority of the patients in our study had 0–2 previous documented attacks (58%), and in many cases the patient recalled undocumented episodes, which were not accounted for in this study. Two percent of all patients were under immunosuppressive medication in both groups; these patients were treated surgically without consideration of the number of previous attacks, to prevent further complications due to recurrent diverticulitis.

Procedure characteristics

Main procedure characteristics like length of hospitalization until surgery, postoperative hospital stay, type of surgery performed, duration of surgery, and experience of

Table 2 Relation between intraoperative assessment of Hinchey classification and histopathological findings

Histology results	Hinchey classification				
	0 (%)	I (%)	IIa (%)	IIb (%)	Total (%)
Diverticulosis only	97 (55)	2 (9)	1 (3)	0	100 (42)
Simple diverticulitis	65 (37)	14 (64)	14 (38)	0	93 (39)
Local mesenteric abscess	13 (7)	3 (14)	10 (27)	0	26 (11)
Locally contained perforation	1 (1)	3 (14)	12 (32)	2 (100)	18 (8)
Total	176 (100)	22 (100)	37 (100)	2 (100)	237 (100)

the surgeon (senior house officer, registrar, consultant/head of department) and the surgical assistant are shown in Table 3. Median hospitalization time to surgery in group A was 9 days (interquartile range [IQR]: 7–11 days). Patients in group B were admitted to the hospital one day prior surgery to allow time for preoperative assessment. The median postoperative hospital stay was 8 days; the range was 4–100 days (IQR 6–10 days) in group A and 3–77 days (IQR 6–11 days) in group B. Only four patients in group A underwent surgery between 15 and 19 days after hospital admission. The main reasons for postponement were late referral from other departments after onset of the acute symptoms, other leading clinical problems, necessity for extended preoperative risk assessment, planned late elective surgery with late onset of impairment of clinical condition, and administrative issues like time slots in the operating schedule.

Mean operative time was 220 min (SD 64) in group A and 202 min (SD 48) in group B. Conversion to laparotomy was necessary in 5% ($n = 12$) of all patients. There was a trend toward higher conversion rate in group A compared to group B (9% versus 3%; $p = 0.070$). In both groups, the main reasons for conversion were difficult anatomy (33%) and peritoneal adhesions (67%).

The main surgical procedure was sigmoid resection in both groups (92% of all cases). The indication for performing an ileocolic resection was diverticulitis of the cecum ($n = 1$). Rectal resections ($n = 10$) were performed to avoid recurrence when inflammation was especially apparent aboral to the sigmoid colon. Left hemicolectomy was necessary in 3% ($n = 7$) of all cases because of extended disease.

In-hospital complications

All in-hospital complications are listed in Table 4. The risk for developing any in-hospital complication (Clavien–Dindo I–V) was 32% in group A and 34% in group B. The risk difference between the two groups was 2% (95% CI: −11%, 14%). According to this confidence interval, the risk of an in-hospital complication could be 11% higher or up to 14% lower in group A compared to group B, and the a priori defined maximal difference of 10% between the treatment strategies could not be maintained. In our multivariable logistic regression analysis of in-hospital complications adjusted for the most important confounders (Table 5), we found an Odds Ratio (OR) for the two treatment groups of 1.11 (95% CI: 0.56, 2.19; $p = 0.772$). The ASA showed a borderline significant influence for developing any in-hospital complication (grade I–V) in both groups (increase by 1 class: OR 1.68, 95% CI: 0.99, 2.84; $p = 0.056$). We could also show that the risk of complications was significantly increased by each decade of the patient's age (OR 1.27, 95% CI: 1.00, 1.60; $p = 0.048$). Despite the heterogeneity between the groups

Table 3 Procedure characteristics

Operation	All ($n = 237$)	Group A ($n = 81$)	Group B ($n = 156$)
Hospitalization until surgery in days, median (IQR)	2 (1–7)	9 (7–11)	1 (1–2)
Hospitalization after surgery in days, median (IQR)	8 (6–10)	8 (6–10)	8 (6–11)
Ileocolic resection	1 (0.4%)	1 (1%)	–
Left hemicolectomy	7 (3%)	2 (2%)	5 (3%)
Sigmoid resection	219 (92%)	76 (94%)	143 (92%)
Rectum resection	10 (4%)	2 (2%)	8 (5%)
Duration of surgery in min, mean (SD)	208 (55)	220 (64)	202 (48)
Experience of surgeon			
Senior house officer	3 (1%)	1 (1%)	2 (1%)
Registrar	73 (31%)	29 (36%)	44 (28%)
Consultant/head of department	160 (68%)	51 (63%)	109 (70%)
Experience of 1st assistant			
Senior house officer	27 (11%)	8 (10 %)	19 (12%)
Registrar	130 (55%)	38 (47%)	92 (59%)
Consultant / Head of Department	79 (33%)	35 (43%)	44 (28%)
Conversion to laparotomy	12 (5%)	7 (9%)	5 (3%)
Reasons for conversion			
Adhesions	4 (2%)	2 (3%)	2 (1%)
Anatomy	8 (3%)	5 (6%)	3 (2%)

Table 4 Surgical complications (several complications per patient possible) and in-hospital complications according to the Clavien–Dindo classification

	All ($n = 237$)	Group A ($n = 81$)	Group B ($n = 156$)
In-hospital complications (Clavien–Dindo classification)			
Stages			
0	158 (67%)	55 (68%)	103 (66%)
I	47 (20%)	18 (22%)	29 (19%)
II	15 (6%)	3 (4%)	12 (8%)
III	15 (6%)	5 (6%)	10 (6%)
IV	1 (0.4%)	0	1 (1%)
V	1 (0.4%)	0	1 (1%)
I–V	79 (33%)	26 (32%)	53 (34%)
Risk for I–V	0.33	0.32	0.34
Surgical complications			
Type of complication			
SSI	10	2	8
Intra-abdominal Abscess	7	1	6
Anastomotic leak	13	5	8
Bleeding	6	2	4
Burst abdomen	1	0	1
Ileus	3	1	2
Others	4	1	3
Total complications	44	12	32
Surgical complications			
At least one	23 (9.7%)	7 (8.6%)	16 (10.3%)
Risk of severe surgical complication	0.10	0.09	0.10

SSI incisional surgical site infection

Table 5 Univariate and multivariable analysis for in-hospital complications coded according to the Clavien–Dindo classification (I–V versus 0) ($n = 236$)

Covariates	Univariate analysis		Multivariate analysis	
	OR (95% CI)	*p* Value	OR (95% CI)	*p* Value
Group A vs group B	1.10 (0.62, 1.95)	0.746	1.11 (0.56, 2.19)	0.772
Histology: diverticulitis vs diverticulosis	0.87 (0.47, 1.58)	0.641	0.81 (0.41, 1.62)	0.558
Histology: locally contained perforation vs diverticulosis	1.09 (0.52; 2.29)	0.815	1.16 (0.49; 2.73)	0.736
Age per decade	1.35 (1.09, 1.68)	0.006	1.27 (1.00, 1.60)	0.048
BMI per 1 unit increase	1.00 (0.94, 1.06)	0.998	1.00 (0.93, 1.06)	0.903
Experience of surgeon (consultant/head of department vs registrar/senior house officer)	0.87 (0.49, 1.55)	0.645	0.75 (0.40, 1.40)	0.366
ASA per 1 class increase	1.89 (1.18, 3.04)	0.008	1.68 (0.99, 2.84)	0.056
Duration of surgery per 10 min increase	0.98 (0.93, 1.03)	0.408	0.97 (0.91, 1.02)	0.245

with regard to the Hinchey classification, severity of disease, assessed by the histopathological findings, did not seem to be an independent predictor for the complications (OR 0.81, 95% CI: 0.41, 1.62; $p = 0.558$ for diverticulitis versus diverticulosis and OR 1.16 95% CI: 0.49, 2.73; $p = 0.736$).

Length of hospital stay

In our multivariate regression model for days from operation to discharge (Table 6), timing of operation (group A versus group B) did not seem to have an effect on length of hospital stay, but it was accompanied by a wide confidence interval (e^{β} 1.04, 95% CI: 0.88, 1.23; $p = 0.620$). Hospitalization time was found to increase by 8% with each decade increase in age (e^{β} 1.08, 95% CI: 1.02, 1.14; $p = 0.005$). Our data showed no clear association between ASA score and longer hospital stay (e^{β} 1.09, 95% CI: 0.97, 1.24 $p = 0.158$). Neither simple diverticulitis (1.01, (95% CI: 0.86, 1.20; p 0.871) nor locally contained perforation (1.02, 95% CI: 0.83, 1.25; $p = 0.883$) in comparison to diverticulosis only had a significant impact on length of postoperative hospital stay.

Surgical complications

The 30 documented severe surgical complications in the two groups included 7 intra-abdominal abscesses, 13 anastomotic leaks, 6 intra-abdominal bleeds, 1 abdominal wall rupture, and 3 occurrences of postoperative ileus exceeding 3 days, which was successfully treated conservatively (Table 4). When a surgical complication developed, most patients had just one of them ($n = 5$, 6% in the early elective surgery group versus $n = 11$, 7% in the late elective surgery group). Two surgical complications per patient occurred in 2.5% in group A and in 3.2% in group B. At least one surgical complication developed in 9% ($n = 7$) in group A and in 10% ($n = 16$) in group B (risk-difference 2%, 95% CI: −6%, 9%). According to the confidence interval, the risk of a surgical complication could be 6% higher or up to 9% lower in group A compared to the group B, and the initially defined maximal difference of 3% between both treatment groups could not be maintained.

Discussion

Laparoscopic sigmoid resection is an accepted approach for elective surgery in diverticulitis, with an increasing popularity [21]. However, the optimal timing of elective surgery, especially in recurrent disease, remains unclear. In the present study we compared early elective (group A) versus late elective surgery (group B) in acute recurrent diverticulitis.

With 237 included patients, this is one of the largest retrospective studies comparing early elective versus late elective surgery in acute diverticulitis. Although only 42% of all patients in our study had ≥3 previous attacks of diverticulitis, the actual numbers might be underestimated, as some patients described undocumented episodes in their past medical history. For in-hospital complications according to the Clavien–Dindo classification and severe

Table 6 Univariate and multivariable analysis for (log transformed) days from operation to discharge ($n = 236$)

Covariates	Univariate analysis		Multivariate analysis	
	e^{β} (95% CI)	p Value	e^{β} (95% CI)	p Value
group A vs. group B	1.02	0.821	1.04	0.620
	(0.88, 1.17)		(0.88, 1.23)	
Histology: diverticulitis vs diverticulosis	1.05	0.529	1.01	0.871
	(0.90, 1.22)		(0.86, 1.20)	
Histology: locally contained perforation vs diverticulosis	1.01	0.910	1.02	0.883
	(0.84; 1.22)		(0.83; 1.25)	
Age per 10 years	1.10	<0.001	(1.02, 1.14)	0.005
	(1.04, 1.15)		1.08	
BMI per 1 unit increase	1.01	0.470	(0.99, 1.02)	0.588
	(0.99, 1.02)		1.00	
Experience of surgeon (consultant/head of department vs registrar/senior house officer)	0.95	0.459	(0.83, 1.11)	0.561
	(0.82, 1.09)		0.96	
ASA per 1 class increase	(1.05, 1.31)	0.006	(0.97, 1.24)	0.158
	1.17		1.09	
Duration of surgery per 10 min increase	(1.00, 1.02)	0.179	(0.99, 1.02)	0.380
	1.01		1.01	

surgical complications, we found a low risk difference of 2% with a tendency toward better outcome in group A. Because the study design was retrospective, and because the wide 95% confidence intervals for the difference in complication rates, which were mainly caused by the low rate of complications, include the a priori defined maximum of 10% for any in-hospital complication and 3% for severe surgical complications, these results may not be definitive. However, although the findings may not serve as the basis for recommendations for the optimal surgical strategy, they are highly informative for the design of future prospective, randomized controlled studies. Except for a trend toward an increased conversion rate in group A, further important issues like severity of diverticulitis, length of hospital stay, and operative time were comparable in the two groups.

The Clavien–Dindo classification [37–39] has been shown to be a valid tool for comparing the incidence of morbidity in surgery. In the present study, both groups showed a low-risk difference of 2%. The multivariate logistic regression analysis, which was adjusted for the most important confounders, showed no significant difference between group A and group B for developing any in-hospital complications. But considering the large 95% CI, which was mainly caused by the limited numbers of complications, the initially defined maximal difference between the two groups of 10% risk could not be maintained, and differences concerning the in-hospital complications between group A and group B could not be definitively excluded. Increase in patient age ($p = 0.048$) and borderline ASA score ($p = 0.056$) were associated with a higher risk of developing any in-hospital complication in both groups. To adjust for the slightly higher risk of in-hospital complications, early elective operation should be recommended to well-selected patients without those risk factors.

Although neither group was homogeneous regarding severity of disease, we could not find a statistically significant difference between them after adjusting for histopathological findings. Considering the limited cases of higher degrees of severity of diverticulitis (19% with mesenteric abscess or locally contained perforation), we nevertheless think that laparoscopic surgery can be performed safely and without any increase of complications in those cases. Surgical complications are among the major outcome parameters that might influence the choice between the two treatment strategies. In contrast to previous published data [2, 17, 22], surgical complications in the present study were slightly lower in group A than in group B. Intra-abdominal abscess, SSI, and anastomotic leak appeared to be the most important surgical complications in this study, which might be explained by the presence of residual inflammatory tissue, especially in group A patients. The slightly lower percentage of severe surgical complications in group A (risk 9% versus 10%) could be interpreted as an advantage compared to group B. But because of the limited number of events and the resulting wide 95% CI, a clear interpretation is difficult.

In summary, with regard to severe surgical complications, a definitive recommendation of the optimal surgical strategy may not be provided based on these results, and the initially defined limit of difference between the two groups could not be complied.

Conversion rate and operative time are two of the most important procedural issues in the evaluation of laparoscopic surgery in diverticulitis, and both have been significant in former studies. One group of investigators could find no difference in conversion rate in both groups [1], however other studies [2, 18, 26] presented higher conversion rates in early elective laparoscopic surgery. Although we found a conversion rate of 9% in group A and 3% in group B, a trend without reaching clear statistical significance ($p = 0.070$), this tendency shouldn't be ignored. It might be explained by the difference between the two groups regarding severity of diverticulitis, assessed by the surgeons' impression and histopathological findings. Group A consisted predominantly of patients with higher stages of diverticulitis, and this might explain the higher conversion rate in this group. Additionally, delayed or reduced response to antibiotic therapy with worsening of symptoms, possible complications in CT-guided drainage of abscesses, persistent inflammation of tissue with adhesions, and impaired individual condition of patients due to inflammation might challenge the laparoscopic approach in early elective surgery and explain the tendency to increased conversion in group A. Although adhesions and anatomical anomalies were the main reasons for conversion in both groups in the present study, the limited number of conversions ($n = 12$) precludes definitive conclusions based on our study. But the tendency for higher conversion rate in group A seems not to have any impact on the further hospital course, characterized by the in-hospital complications and the postoperative length of hospital stay.

Considering guidelines and the clinical pathway of our clinic, which recommends setting the indication for surgery in acute recurrent diverticulitis based on repeated clinical assessment of the patient and response to antibiotic treatment, we included severity of diverticulitis as a clinical marker in our multivariable analysis (Tables 5, 6). Neither simple diverticulitis nor locally contained perforation showed any significant impact on outcome in our results. So we conclude that severity of diverticulitis might practically have had an influence on setting indication for surgery but did not had any effect on outcome. From the results obtained, we note differences between the intraoperative assessment of severity of diverticulitis (Hinchey classification) and the histopathological findings (Table 2). The surgeons oversaw simple diverticulitis and even mesenteric abscesses, when Hinchey 0–diverticulosis only—was described in the operation report. With higher Hinchey stage, the variety of histopathological findings increased. Once the inflammation is more extended in the tissue it seems to be difficult for the surgeon to assess the severity of diverticulitis by using the Hinchey classification. Because intraoperative findings may influence further treatment, and because the surgeon's observations do not correspond with the histopathological findings in our study, further treatment based on intraoperative assessment in non-perforated Hinchey stages (0–IIb) should be carried out with reservation.

Due to patients' needs such as increased comfort and avoiding unnecessary days of hospitalization, early elective surgery has become increasingly popular. Both group A and group B had a postoperative hospital stay of 8 days, which is comparable to other studies [1, 2, 17, 22]. As presented in our multivariate analysis, neither timing of operation nor severity of diverticulitis had a significant impact on length of hospital stay. Only increased age was associated with a longer hospital stay, which might be an effect of reduced mobility, co-morbidities, and delays in setting up outpatient care for the elderly patients. Although the total length of hospital stay, including the conservative treatment phase in group B, is equal, patients in the early elective setting had only one hospitalization, which enhanced patient comfort.

A recent study has shown slightly reduced overall treatment costs in early elective treatment of recurrent diverticulitis compared to late elective surgery [22]. Considering the unknown costs of conservative treatment prior to surgery and the differing compilation of health costs in hospitals worldwide, no clear conclusion could be drawn from our study regarding costs of early versus late elective surgery in diverticulitis.

In conclusion, given the retrospective design of the present study, and the fact that the confidence interval for the difference in severe surgical and overall postoperative complication rates includes the prespecified maxima of 3 and 10%, respectively, a definitive recommendation for the optimal timing of elective surgery for acute diverticulitis cannot be provided based on these results. A slightly higher conversion rate in group A was offset by the advantage of a single hospitalization. Additionally, severity of disease showed no effect on outcome and may therefore be overestimated as a prognostic factor for the further hospital course. Hence our results might support the strategy of early elective surgery in diverticulitis but need further clarification. For the time-being, the optimal strategy should be defined on a case-by-case basis. Nevertheless, our study can be seen as an important contribution to the ongoing discussion regarding optimal timing in laparoscopic surgery in recurrent diverticulitis. Our findings are of great relevance for the design of prospective trials, because they show the limits of retrospective analysis, even with validated assessment tools, multivariate analysis models, and including a high number of patients. Another retrospective study might not clarify the controversies regarding early elective or late elective surgery in acute recurrent diverticulitis. However, this study, together with previous findings, ethically justifies the conduct of a prospective randomized controlled trial (early elective versus late elective) in patients with recurrent acute complicated diverticulitis.

Conflict of interest There are no potential and real conflicts of interest.

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