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Long-term follow-up of a multicentre cohort study on laparoscopic peritoneal lavage for perforated diverticulitis

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Abstract

Aim Laparoscopic peritoneal lavage has increasingly been investigated as a promising alternative to sigmoidectomy for perforated diverticulitis with purulent peritonitis. Most studies only reported outcomes up to 12 months. Therefore, the objective of this study was to evaluate long-term outcomes of patients treated with laparoscopic lavage.

Methods Between 2008 and 2010, 38 patients treated with laparoscopic lavage for perforated diverticulitis in 10 Dutch teaching hospitals were included. Long-term follow-up data on patient outcomes, e.g. diverticulitis recurrence, reoperations and readmissions, were collected retrospectively. The characteristics of patients with recurrent diverticulitis or complications requiring surgery or leading to death, categorized as 'overall complicated outcome', were compared with patients who developed no complications or complications not requiring surgery.

Results The median follow-up was 46 months (interquartile range 7–77), during which 17 episodes of recurrent diverticulitis (seven complicated) in 12 patients (32%) occurred. Twelve patients (32%) required additional surgery with a total of 29 procedures. Fifteen patients (39%) had a total of 50 readmissions. Of initially successfully treated patients (n = 31), 12 (31%) had recurrent diverticulitis or other complications. At 90 days, 32 (84%) patients were alive without undergoing a sigmoidectomy. However, seven (22%) of these patients eventually had a sigmoidectomy after 90 days. Diverticulitis-related events occurred up to 6 years after the index procedure.

Conclusion Long-term diverticulitis recurrence, reintervention and readmission rates after laparoscopic lavage were high. A complicated outcome was also seen in patients who had initially been treated successfully with laparoscopic lavage with relevant events occurring up to 6 years after initial surgery.

Keywords Laparoscopic lavage, perforated diverticulitis, long-term follow-up

What does this paper add to the literature?

Laparoscopic lavage for perforated diverticulitis has increasingly been investigated, but long-term data are scarce. With a median follow-up of 46 months, this paper reports on long-term outcomes after laparoscopic lavage and shows long-term diverticulitis recurrence, reintervention and readmission rates after laparoscopic lavage to be high.

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Introduction

Diverticular disease is a common problem in developed countries, resulting in an estimated annual rate of up to 786 000 hospital admissions in Europe [1]. Of patients with acute diverticulitis 8%–35% present with abscess formation or peritonitis (modified Hinchey Grades Ib–IV), resulting in an estimated 60 000 perforated diverticulitis cases per year in Europe [1–5]. Perforated diverticulitis with generalized peritonitis requires surgical treatment in most cases. Nevertheless, both the Hartmann procedure (HP) and sigmoidectomy with primary anastomosis (PA) have been associated with significant morbidity and mortality rates [6–8]. Therefore, after its introduction in 1996, laparoscopic peritoneal lavage (LL) has increasingly been investigated as a promising alternative to sigmoidectomy [9–17]. Despite initial promising results, recent randomized controlled trials showed increased rates of severe postoperative complications and reoperations compared with sigmoidectomy [18–23].

Current studies on LL predominantly report on outcomes up to 12 months after surgery [13,14,16,17,24–26]. Reports on the long-term consequences of LL as therapy for perforated diverticulitis are scarce [27–29]. Therefore, further exploration of long-term outcomes is of importance, since leaving the diseased colonic segment *in situ* after LL potentially puts patients at increased risk for both uncomplicated and complicated diverticulitis recurrence, which might necessitate surgery [3,19,23]. Additionally, long-term outcomes of patients treated with LL potentially could provide relevant insights into which patients might benefit most from this treatment [26].

Therefore, the aim of this study was to assess the long-term outcomes of a previously published cohort study of patients treated with LL for perforated diverticulitis, with regard to diverticulitis recurrence, subsequent related complications and surgical interventions [25].

Method

A multicentre, retrospective cohort study was performed. The study was approved by the institutional review boards of all participating hospitals. Due to the retrospective design, informed consent was waived for participation in this study. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations for reporting of observational studies were followed [30]. Detailed methods of the short-term follow-up of this study were published previously by Swank *et al.* [25].

Patient inclusion

Patients treated with LL for perforated diverticulitis in 10 Dutch teaching hospitals between 1 January 2008 and 31 December 2010 were included [25]. Patient records were screened for the diagnosis ‘diverticulitis’ or ‘acute abdomen’, and subsequently operation type was recorded. Patients who underwent LL as primary treatment for complicated diverticulitis with free air and/or purulent peritonitis were included.

Data collection: short-term follow-up

Baseline patient demographics, such as comorbidities, American Society of Anesthesiologists (ASA) score, preoperative white blood cell count, C-reactive protein (CRP) and the results of preoperative X-ray or computed tomography (CT) scan were recorded previously. Furthermore, operative records were screened, and short-term recurrent diverticulitis, numbers and types of complications, diagnostic measures, re-interventions and readmissions were recorded.

Data collection: long-term follow-up

In the present study, additional long-term data collection was performed through a retrospective review of patient records. All events are reported jointly in this study. Short-term follow-up was defined as the first 90 days after index surgery; long-term follow-up consisted of the period thereafter. During long-term follow-up, patient records were screened for survival status, readmissions, re-interventions, complicated or uncomplicated diverticulitis recurrence, development of fistulas, intra-abdominal abscesses, colonic stenosis or other potentially related complications, as well as colonoscopies and abdominal CT scans, diagnosis of colorectal malignancies (e.g. rectosigmoid) and midline incisional or parastomal hernias.

Outcome parameters

Primary treatment failure of LL was defined as ongoing abdominal sepsis. Long-term outcomes of patients without a sigmoidectomy at 90 days of follow-up after the index procedure were assessed. The modified Hinchey classification was used to categorize patients according to the intra-operative findings [5]. The Mannheim Peritonitis Index was used as predictor of the mortality risk [31]. Recurrent diverticulitis episodes were classified as either uncomplicated or complicated based on the information available from patient records. Diverticulitis episodes were classified as complicated when associated with perforation, abscess formation, fistulas, stenosis or diverticular bleeding [32]. Clinical follow-up was calculated as the time between the index admission and the last recorded hospital visit and, additionally, total study follow-up was calculated as the time between the index admission and the time of data extraction by the researcher (D.S. or D.L.). 'Overall complicated outcome' was defined as postoperative complications or recurrent diverticulitis requiring surgery or resulting in mortality. To identify potential risk factors for an overall complicated outcome during follow-up, patients with and without a complicated outcome were compared.

Statistical analysis

Statistical analysis was performed using SPSS statistics (Version 24, IBM, Armonk, NY, USA). Continuous variables are presented as medians with interquartile range (IQR) or means with standard deviation (±SD), depending on the normality of the data. Discrete variables are presented as numbers (n) with percentages (%). Depending on the data distribution Student's t test or the Mann–Whitney U test, as appropriate, was used for comparison of continuous variables. Fisher's exact test was used for comparing discrete variables with two categories and a chi-squared test was used for discrete variables with three or more categories. A P value of < 0.05 was considered statistically significant.

Results

Baseline characteristics

Medical records were screened for potentially eligible patients in 34 Dutch hospitals. Eventually, from 10 of these hospitals, 38 patients were included who were treated for Hinchey Grade II or III diverticulitis by means of LL. Baseline characteristics are summarized in Table 1 and were previously described by Swank *et al.* [25]. One or more comorbidities were present in 18 patients, consisting of cardiovascular disease ($n = 8$), previously diagnosed malignant disease ($n = 5$), hypertension ($n = 3$) and chronic obstructive pulmonary disease ($n = 2$). None of the included patients had a previous episode of diverticulitis, two patients had previous abdominal surgery not related to diverticular disease, and one patient suffered from respiratory insufficiency before the LL procedure.

Overall outcomes

Short-term (< 90 days) and long-term follow-up are summarized in Tables 2–4 and Fig. 1. The number of recurrent diverticulitis episodes and surgical re-interventions for 1-, 3- and 5-year intervals as well as until the end of follow-up are presented in Table 5. Patient records were examined after a median of 90 months (84–96). Median clinical follow-up, as defined earlier, was 46 months (7–77). During the entire follow-up period, 27 (71%) patients had at least one adverse event. In 12 patients (32%), 17 recurrent episodes of diverticulitis (seven complicated and 10 uncomplicated) were reported. The median time between LL and first recurrence of diverticulitis was 341 days (range 61–2119, IQR 115–795). Recurrence-free survival is presented in Fig. 2. The median time to sigmoidectomy was 240 days (range 2–1406); resection-free survival is shown in Fig. 3. Twenty-nine subsequent surgical procedures among 12 patients (32%) were reported, of whom seven had emergency surgery at least once. In total, four patients (11%) died due to causes related to or as a direct consequence of their diverticular disease, including multiple organ failure ($n = 2$), persisting ileus ($n = 1$) and aspiration pneumonia ($n = 1$). Four patients died due to unrelated causes: breast cancer ($n = 1$), retroperitoneal bleeding ($n = 1$), brain tumour ($n = 1$) and cardiovascular disease ($n = 1$). At least one follow-up colonoscopy or sigmoidoscopy ($n = 25$) or CT scan ($n = 23$) was performed in 31 patients. Extensive diverticulosis was reported in 19 (61%) of these patients. One patient was diagnosed with rectal cancer during follow-up.

Follow-up in patients with initially controlled abdominal sepsis

LL succeeded in controlling the abdominal sepsis in 31 patients. During short-term follow-up, one patient had emergency surgery for repair of a fascial dehiscence. Although abdominal sepsis was controlled, one patient died due to a persisting obstructive ileus 27 days after the index procedure. This patient was diagnosed with terminal lung cancer and it was therefore decided not to perform further surgery.

At long-term follow-up, 30 out of 31 patients successfully treated with LL were alive. Eleven of these patients (36.7%) developed either a recurrent episode of diverticulitis or other complications and six patients (20%) required additional surgery. These patients were diagnosed with recurrent complicated diverticulitis ($n = 5$), recurrent uncomplicated diverticulitis ($n = 4$), obstructive ileus ($n = 3$), intra-abdominal abscesses ($n = 6$), fistula formation ($n = 3$), midline incisional hernia ($n = 2$), parastomal hernia (after sigmoidectomy) ($n = 2$) and wound infection ($n = 1$). Additional surgical interventions for these patients consisted of sigmoidectomy ($n = 5$), low anterior resection ($n = 1$), end colostomy construction ($n = 1$), obstructive ileus relief ($n = 2$), fistulotomy with simultaneous abscess drainage ($n = 1$), parastomal hernia repair ($n = 1$) and stoma reversal ($n = 4$).

Table 1 Baseline characteristics.

No. of patients	38
Sex ratio (M:F)	24:14
Age (years)*	59 (45.5–68.3)
ASA score	
1–2	23
3–4	15
Comorbidities	
None	20
1	6
2	6
> 2	6
Mannheim Peritonitis Index †	13.3 ± 5
Preoperative CRP (mM) †	203 ± 143
Preoperative WBC count (× 10^3/mm^3)†	15.4 ± 5.3
Preoperative hospital stay (days)†	
0	28
1	5
2	2
≥ 2	3
Free air	
No imaging	3
None	3
Pericolic	4
Distant	28
Operative findings	
Pelvic abscess, diffuse free air on CT (Hinchey II)	5
Localized cloudy or purulent exudate (Hinchey III)	29
Generalized cloudy or purulent exudate (Hinchey III)	4
Overt perforation	
Yes	2
No	36

ASA, American Society of Anesthesiologists; CRP, C-reactive protein; WBC, white blood cell; CT, computed tomography. Continuous values are *median (IQR) and †mean ± SD; discrete variables are absolute numbers.

Follow-up in patients with initial failure of laparoscopic lavage

LL did not succeed in controlling abdominal sepsis in seven patients. All these patients developed complications requiring surgery or died from related causes. During short-term follow-up five patients underwent one or more surgical procedures: sigmoidectomy (n = 3), loop ileostomy construction (n = 1), repair of a perforated sigmoid (n = 1), two surgical abscess drainages (n = 1) and repair of fascial dehiscence (n = 1). Two patients required, but could not undergo, emergency laparotomy due to their deteriorating condition. Both patients died after the index procedure due to multiple organ failure after 5 and 37 days, respectively.

Table 2 Overall outcomes.

	Overall outcomes
No. of patients	38
Clinical follow-up (months)*	46 (7–77)
Study follow-up (months)*	90 (84–96)
Overall mortality	8 (21)
Total index admission time (days)*	14 (12–23)
ICU admission	6 (16)

Continuous variables are *median (IQR); discrete variables are absolute numbers (%).

At long-term follow-up five out of seven patients who initially were unsuccessfully treated with LL were alive. Four of these patients developed either a recurrent episode of diverticulitis or other complications and were subsequently operated upon: recurrent complicated diverticulitis (n = 1), recurrent uncomplicated diverticulitis (n = 1), fistula formation (n = 2) or obstructive ileus (n = 1). Additional surgical interventions consisted of incisional hernia repair (n = 2), surgical excision of an ileosigmoid fistula (n = 1) and stoma reversal (n = 3). One patient died due to aspiration pneumonia following ileostomy reversal.

Follow-up in patients without sigmoidectomy at 90 days

At 90 days after the index procedure, 32 (84%) patients were still alive and did not have an initial sigmoidectomy. A total of 15 recurrent episodes of diverticulitis were reported among 10 (31%) of these patients, of whom five patients had a complicated recurrence. Of these, seven (22%) underwent further surgery, six patients underwent a sigmoidectomy and one patient received a wedge excision of the sigmoid colon. Indications for surgery were recurrent diverticulitis (n = 5), obstructive ileus (n = 1) and sigmoid perforation (n = 1). Other procedures in these seven patients were relief of obstructive ileus (n = 2), repair of parastomal hernia (n = 1) and stoma reversal (n = 5). A stoma was constructed in six of these patients (three loop ileostomies and three end colostomies).

Univariate analysis

Results of the univariate analysis are given in Table 6. Baseline characteristics of patients with an overall complicated follow-up were compared with patients who developed no complications or complications not requiring surgery. Primary treatment failure (OR 3.9, 95% CI 2.13–7.04; P = 0.001) was associated with a

Table 3 Recurrent diverticulitis, morbidity, and surgical re-interventions.

	< 90 days	≥ 90 days	Combined	Total events
Recurrent diverticulitis				
Sepsis not controlled/ongoing diverticulitis	7 (18)	0	7 (18)	7
Overall recurrence	1 (3)	11 (29)	12 (32)	17
1	1	8	9	9
≥ 2	0	3	3	8
Uncomplicated diverticulitis	1 (3)	5 (13)	6 (18)	10
Complicated diverticulitis	0	6 (16)	6 (18)	7
1	0	5	5	5
≥ 2	0	1	1	2
Time until first episode (days)		341 (115–795)		–
Morbidity				
Ileus	5 (13)	4 (11)	9 (24)	12
After laparoscopic lavage	5	1	6	6
After subsequent surgery	0	3	3	6
Intra-abdominal abscess	4 (11)	5 (13)	8 (23)	11
Enterocutaneus/enterovaginal/enterovesical/ileosigmoid fistula	3 (8)	4 (11)	6 (18)	7
Midline incisional hernia	2 (5)	2 (5)	4 (11)	4
Burst abdomen	2 (5)	0	2 (5)	2
Parastomal hernia	0	2 (5)	2 (5)	2
Wound infection	2 (5)	1 (3)	3 (8)	3
Pneumonia	2 (5)	0	2 (5)	2
Pulmonary embolism	1 (3)	0	1 (3)	1
Atrial fibrillation	1 (3)	0	1 (3)	1
Surgical re-interventions				
Overall	6 (18)	10 (26)	12 (32)	29
1	4	4	2	2
≥ 2	2	6	10	10
≥ 1 emergency procedures	6 (100)	2 (20)	7 (58)	11
Sigmoid/anterior resection	3 (8)	6 (16)	9 (24)	9
Wedge excision sigmoid	0	1 (3)	1 (3)	1
Suture repair of perforated sigmoid	1 (3)	0	1 (3)	1
Stoma construction	3 (8)	6 (16)	9 (24)	9*
End colostomy	2	4	6	6
Loop ileostomy	1	2	3	3
Stoma reversal	0	7	7	7
(Parastomal) hernia repair	0	3 (8)	3 (8)	3†
Relief of obstructive ileus	0	2 (5)	2 (5)	2
Abscess drainage (surgical)	1 (3)	0	1 (3)	2
Fistulotomy and abscess drainage	0	1 (3)	1 (3)	1
Repair of fascia dehiscence	2 (5)	0	2 (5)	2

Continuous variables are median (IQR); discrete variables are absolute numbers (%). Events that occurred multiple times are counted as one event per patient; the total events column depicts the cumulative number of events.

*One ileostomy and one colostomy were constructed in a separate procedure.

†One hernia repair procedure was performed simultaneously with a colostomy reversal.

complicated outcome. Additionally, multiple (≥ 2) pre-operative comorbidities (OR 5.43, 95% CI 1.24–23.90; $P = 0.033$) and ASA ≥ 3 (OR 7.2, 95% CI 1.67–31.03; $P = 0.008$) were correlated with a complicated outcome. Median CRP appeared to be higher in those patients with an overall complicated outcome. However, no statistically significant difference was found [172 mM (IQR 50–275) *vs* 242 mM (IQR 128.5–323), $P = 0.068$].

Discussion

The present retrospective cohort study evaluated the long-term outcomes of 38 patients treated with LL for

Table 4 Readmissions.

Readmissions	Overall outcomes	Total events
Any readmission	15 (39)	50
1	4	4
≥ 2	11	46
Total readmission time (days)	11 (4–29)	346

Continuous variables are median (IQR); discrete variables are absolute numbers (%).

perforated diverticulitis in 10 centres in the Netherlands. Although the initial results in this patient cohort were promising, during long-term follow-up a significant number of patients had subsequent recurrent diverticulitis or developed other related complications with relevant events occurring up to 6 years after initial surgery. In patients with an initially successful outcome, complications and subsequent surgery frequently occurred.

In our study, nine patients (24%) underwent sigmoidectomy during follow-up. In previous reports on long-term outcomes after LL, sigmoidectomy rates of 44.7% and 21% were reported [28,29]. In the cohort presented by White *et al.* [28], 44.7% of patients underwent sigmoidectomy. However, eight LL patients received a planned sigmoidectomy before severe symptoms of recurrence were present. These eight patients potentially resulted in an overestimate of the sigmoidectomy rate. In our cohort there was no intention to treat patients by elective sigmoidectomy unless otherwise

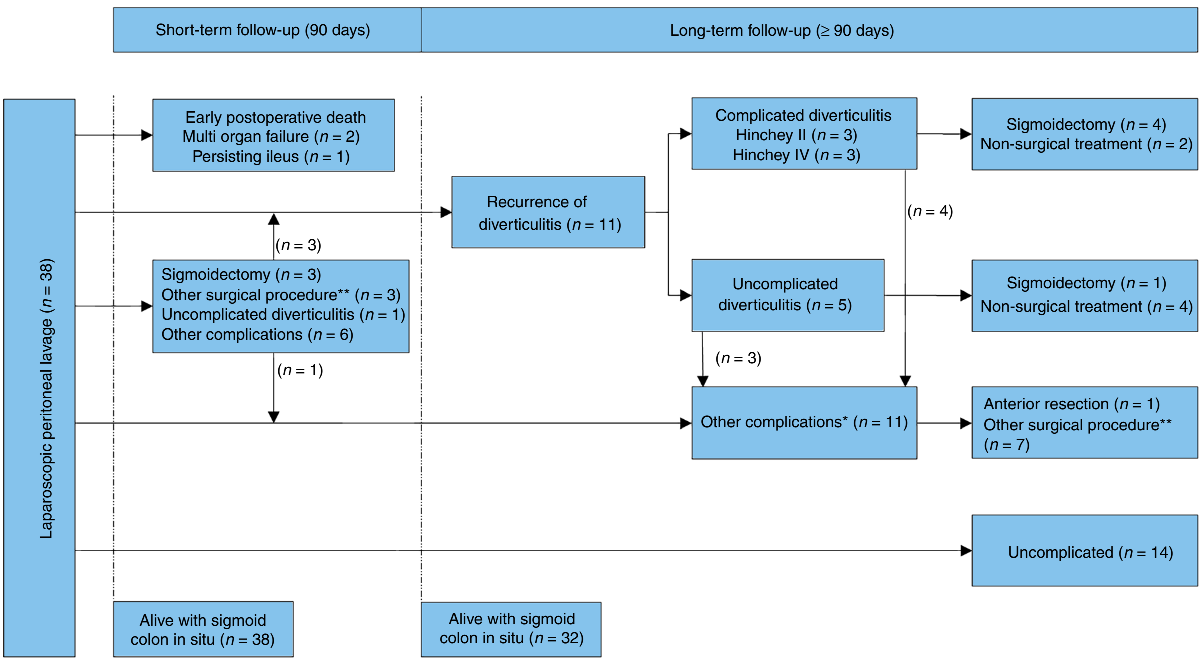

Figure 1 Flowchart of clinical outcomes. Non-surgical treatment comprises all medical interventions not requiring general anaesthesia including radiological interventions (e.g. intravenous antibiotics and fluid therapy or endoscopic dilatation). *Other complications comprise ileus, intra-abdominal abscesses, fistulas, multi-organ failure, incisional hernias and parastomal hernias. **Other surgical procedures comprise stoma construction, stoma reversal, (parastomal) hernia repair, relief of obstructive ileus, repair of fascial dehiscence, repair of sigmoid perforation, fistulotomy, abscess drainage, wedge resection of the sigmoid. The number of patients who had multiple events is indicated in parentheses next to the arrows.

Table 5 Recurrence of diverticulitis and surgical re-interventions by time period.

Time interval	0–1 year	0–3 years	0–5 years	End of follow-up
Recurrence of diverticulitis	8	13	16	17
Sigmoid/anterior resection	7	8	9	9
Reoperations	19	24	27	29

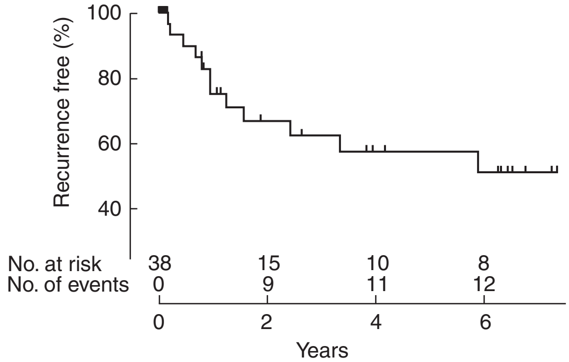

Figure 2 Recurrence-free survival.

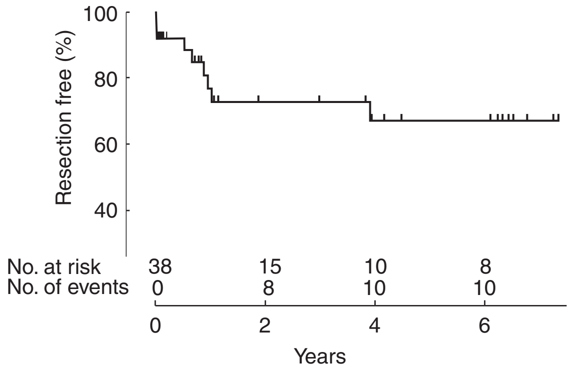

Figure 3 Resection-free survival.

indicated during follow-up. The sigmoidectomy rate reported at 2-year follow-up in the DILALA trial was 21% (n = 43) [13,29]. In the recently published LLO Study, the overall reoperation rate was 26% (56/212 patients) [33]. Furthermore, the recurrence rate was 27% (47/172 patients) in patients without re-interventions during admission and the first 60 postoperative days. Both studies present results comparable to the present cohort; however, follow-up in these studies was shorter, and therefore reported event rates may still increase.

A potential major advantage of LL for the treatment of perforated diverticulitis is the avoidance of HP with construction of an end colostomy or PA with a loop ileostomy, especially since after HP colostomies may be reversed in only 50%–60% of patients [34,35]. In our cohort, 32 (84%) patients were alive without undergoing a sigmoidectomy at 90 days. Overall, a stoma could be avoided in the majority (76%) of patients and most patients who did receive an end colostomy or loop ileostomy eventually had their stoma reversed (78%).

Leaving the diseased colonic segment *in situ* puts patients potentially at increased risk for both uncomplicated and complicated diverticulitis, which might necessitate surgery [19,23]. A complicated outcome was present in 26% of patients who initially had been successfully treated with LL. Seven out of 32 had recurrent complaints necessitating six sigmoidectomies and one wedge incision (22%) at long-term follow-up. Therefore, controlling the abdominal sepsis after LL does not guarantee favourable long-term outcomes. In addition, as shown in the present study, ongoing abdominal sepsis after LL is predictive of an overall complicated outcome during both short-term and long-term follow-up. In those cases, early sigmoidectomy may be necessary. Although the present study does not provide enough evidence to draw a definitive conclusion, it raises the question whether planned sigmoidectomies to avoid long-term sequelae should be considered during the follow-up of patients fit for surgery.

Considering the additional events during long-term follow-up, both high ASA scores ($\geq$ 3) and the presence of two or more comorbidities, regardless of their nature or treatment, were associated with an unfavourable prognosis. This is largely in accordance with two previous studies identifying risk factors for the failure of LL [26,33]. Due to the relatively small sample size, multivariate analysis was not performed in this study. High preoperative CRP values have previously been associated with negative outcomes and increased histological damage to the colon in patients with diverticulitis [36,37]. Therefore, it is conceivable that high preoperative CRP levels might have some predictive value for overall unfavourable outcomes after LL. Although median CRP appeared to be higher in those patients with an overall complicated outcome, this association was not confirmed in the current study.

This study has several limitations of which most are inherent to its retrospective observational design. The study cohort is at risk for selection bias, as the decision to treat patients with LL was made clinically. At the time of patient inclusion, patients with a more favourable prognosis might have been selected more often to undergo this treatment. Furthermore, no control patients undergoing primary resection were included in the cohort to compare long-term results of both treatment strategies. Additionally, the retrospective study design might have led to heterogenic and potentially incomplete follow-up, which could underestimate the number of adverse events. Nevertheless, despite this, the event rate was still considerable. Finally, given the small sample size of the study, the results should be interpreted with caution.

To date, three randomized studies and several subsequent meta-analyses comparing LL to primary resection have been published [16,17,19–24,38]. However, three of these meta-analyses are criticized as having

Table 6 Univariate analysis of baseline characteristics.

Variable	Uncomplicated follow-up	Complicated follow-up	*P* value
N	23	15	
Sex ratio (M:F)	15:8	9:6	1.00
Age	58 (44–68)	60 (46–70)	1.00*
ASA score			
1–2	18	5	0.008
3–4	5	10	
Comorbidities			
0 or 1	19	7	0.033
≥ 2	4	8	
Mannheim Peritonitis Index*	11 (10–16)	15 (11–16)	0.184*
Preoperative CRP (mm)*	172 (50–275)	242 (128.5–323)	0.068*
Preoperative white blood cell count ($\times 10^3$/mm^3)*	16 (13.6–19.6)	13.4 (10.2–19.3)	0.374*
Preoperative hospital stay (days)			
0 or 1	19	14	0.630
≥ 2	4	1	
Free air			
No	1	2	0.545
Pericolic	3	1	
Distant	16	12	
Per operative diagnosis			
Pelvic abscess, diffuse free air on CT (Hinchey II)	2	3	0.504
Localized cloudy or purulent exudate (Hinchey III)	19	10	
Generalized cloudy or purulent exudate (Hinchey III)	2	2	
Overt perforation	1	1	1.00
Primary treatment failure	0	7	0.001

Continuous values are median (IQR); discrete variables are absolute numbers. ASA, American Society of Anesthesiologists; CRP, C-reactive protein; CT, computed tomography.
*Mann–Whitney *U* test.

methodological errors and provide discrepant conclusions [39]. Therefore, the effectiveness of LL remains a topic for debate. Two meta-analyses reported increased reoperation and morbidity rates in LL patients at 3 months, whereas at 12 months the reoperation rate was reported to be higher in the primary resection patients [20,21]. The recently published 2-year results of the DILALA trial showed significantly fewer surgical interventions in patients treated with LL compared to HP [13,29]. However, these results have to be interpreted with caution as the increased reoperation rates in the patients who had HP is largely attributed to stoma reversal procedures. Additionally, during the second follow-up year, eight patients in the LL group developed recurrent diverticulitis compared with only two in the HP group. As shown in the present study, recurrence rates may occur well after 2 years. Due to the limited follow-up of most previous trials, complication and recurrence rates after LL are probably underestimated. Based on 12-month outcomes, LL was reported to be cost-effective in two studies [40,41]. However, considering that related interventions and readmissions could potentially occur after 12 months, the actual related costs of LL may be higher. Nevertheless, LL may result in the avoidance of a stoma and an uncomplicated follow-up in selected patients. Interestingly, in our cohort, 42% of patients had an ASA score of ≥ 3, which correlated with a complicated outcome. Evidently, the present report is preliminary and should be interpreted with caution. Nevertheless, it appears that LL predominantly results in morbidity and mortality in frail patients (e.g. those with high ASA scores or multiple comorbidities). LL may be viable as the primary treatment option in a selected population. Therefore, accurate selection of patients that might benefit from this treatment is of importance to obtain satisfactory results, e.g. by taking age, immunosuppression, severe comorbidities (ASA ≥ 3), mannheim peritonitis index and history of acute diverticulitis into consideration [26,33]. Long-term follow-up of other randomized controlled trials comparing LL to sigmoidectomy will provide more data on the efficacy and cost-effectiveness, as well as other studies assessing potential risk factors of treatment failure, and might help to improve accurate patient selection for LL.

Conclusion

In this retrospective cohort of 38 patients treated with LL for perforated diverticulitis, long-term recurrence, re-intervention and readmission rates were high. Moreover, a complicated outcome was also present in patients who had initially been treated successfully with LL with relevant events occurring up to 6 years after initial surgery. Potentially, multiple comorbidities, high ASA scores and short-term treatment failure of LL are of predictive value for an overall complicated outcome.

Conflicts of interest

The authors declare no conflicts of interest.

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References

1 Delvaux M. Diverticular disease of the colon in Europe: epidemiology, impact on citizen health and prevention. *Aliment Pharmacol Ther* 2003; **18:** 71–4.
2 Li D, Baxter NN, McLeod RS, Moineddin R, Wilton AS, Nathens AB. Evolving practice patterns in the management of acute colonic diverticulitis: a population-based analysis. *Dis Colon Rectum* 2014; **57:** 1397–405.
3 Shahedi K, Fuller G, Bolus R *et al.* Long-term risk of acute diverticulitis among patients with incidental diverticulosis found during colonoscopy. *Clin Gastroenterol Hepatol* 2013; **11:** 1609–13.
4 Hinchey EJ, Schaal PG, Richards GK. Treatment of perforated diverticular disease of the colon. *Adv Surg* 1978; **12:** 85–109.
5 Wasvary H, Turfah F, Kadro O, Beauregard W. Same hospitalization resection for acute diverticulitis/Discussion. *Am Surg* 1999; **65:** 632.
6 Constantinides VA, Tekkis PP, Athanasiou T *et al.* Primary resection with anastomosis vs. Hartmann's procedure in nonelective surgery for acute colonic diverticulitis: a systematic review. *Dis Colon Rectum* 2006; **49:** 966–81.
7 Salem L, Flum DR. Primary anastomosis or Hartmann's procedure for patients with diverticular peritonitis? A systematic review. *Dis Colon Rectum* 2004; **47:** 1953–64.
8 Thornell A, Angenete E, Haglind E. Perforated diverticulitis operated at Sahlgrenska University Hospital 2003–2008. *Dan Med Bull* 2011; **58:** A4173.
9 O'Sullivan GC, Murphy D, O'Brien MG, Ireland A. Laparoscopic management of generalized peritonitis due to perforated colonic diverticula. *Am J Surg* 1996; **171:** 432–4.
10 Rizk N, Champault G, eds. Laparoscopic treatment in two operative stages of perforated sigmoid diverticulitis: 2 cases. *Ann Chir* 1995; **50:** 283.
11 Toorenvliet BR, Swank H, Schoones JW, Hamming JF, Bemelman WA. Laparoscopic peritoneal lavage for perforated colonic diverticulitis: a systematic review. *Colorectal Dis* 2010; **12:** 862–7.
12 Myers E, Hurley M, O'Sullivan GC, Kavanagh D, Wilson I, Winter DC. Laparoscopic peritoneal lavage for generalized peritonitis due to perforated diverticulitis. *Br J Surg* 2008; **95:** 97–101.
13 Thornell A, Angenete E, Bisgaard T *et al.* Laparoscopic lavage for perforated diverticulitis with purulent peritonitis: a randomized trial. *Ann Intern Med* 2016; **164:** 137–45.
14 Schultz JK, Wallon C, Blecic L *et al.* One-year results of the SCANDIV randomized clinical trial of laparoscopic lavage versus primary resection for acute perforated diverticulitis. *Br J Surg* 2017; **104:** 1382–92.
15 Swank HA, Vermeulen J, Lange JF *et al.* The Ladies trial: laparoscopic peritoneal lavage or resection for purulent peritonitis and Hartmann's procedure or resection with primary anastomosis for purulent or faecal peritonitis in perforated diverticulitis (NTR2037). *BMC Surg* 2010; **10:** 29.
16 Vennix S, Musters GD, Mulder IM *et al.* Laparoscopic peritoneal lavage or sigmoidectomy for perforated diverticulitis with purulent peritonitis: a multicentre, parallel-group, randomised, open-label trial. *Lancet* 2015; **386:** 1269–77.
17 Angenete E, Thornell A, Burcharth J *et al.* Laparoscopic lavage is feasible and safe for the treatment of perforated diverticulitis with purulent peritonitis: the first results from the randomized controlled trial DILALA. *Ann Surg* 2016; **263:** 117–22.
18 Afshar S, Kurer MA. Laparoscopic peritoneal lavage for perforated sigmoid diverticulitis. *Colorectal Dis* 2012; **14:** 135–42.
19 Marshall JR, Buchwald PL, Gandhi J *et al.* Laparoscopic lavage in the management of Hinchey Grade III diverticulitis: a systematic review. *Ann Surg* 2017; **265:** 670–6.
20 Ceresoli M, Coccolini F, Montori G, Catena F, Sartelli M, Ansaloni L. Laparoscopic lavage versus resection in perforated diverticulitis with purulent peritonitis: a meta-analysis of randomized controlled trials. *World J Emerg Surg* 2016; **11:** 42.
21 Angenete E, Bock D, Rosenberg J, Haglind E. Laparoscopic lavage is superior to colon resection for perforated purulent diverticulitis – a meta-analysis. *Int J Colorectal Dis* 2017; **32:** 163–9.
22 Cirocchi R, Di Saverio S, Weber DG *et al.* Laparoscopic lavage versus surgical resection for acute diverticulitis with generalised peritonitis: a systematic review and meta-analysis. *Tech Coloproctol* 2017; **21:** 93–110.
23 Penna M, Markar SR, Mackenzie H, Hompes R, Cunningham C. Laparoscopic lavage versus primary resection for acute perforated diverticulitis: review and meta-analysis. *Ann Surg* 2018; **267:** 252–8.
24 Schultz JK, Yaqub S, Wallon C *et al.* Laparoscopic lavage vs primary resection for acute perforated diverticulitis: the

SCANDIV randomized clinical trial. *JAMA* 2015; **314:** 1364–75.

25 Swank HA, Mulder IM, Hoofwijk AG *et al.* Early experience with laparoscopic lavage for perforated diverticulitis. *Br J Surg* 2013; **100:** 704–10.

26 Greilsamer T, Abet E, Meurette G *et al.* Is the failure of laparoscopic peritoneal lavage predictable in Hinchey III diverticulitis management? *Dis Colon Rectum* 2017; **60:** 965–70.

27 Liang S, Russek K, Franklin ME. Damage control strategy for the management of perforated diverticulitis with generalized peritonitis: laparoscopic lavage and drainage vs. laparoscopic Hartmann's procedure. *Surg Endoscopy* 2012; **26:** 2835–42.

28 White SI, Frenkiel B, Martin PJ. A ten-year audit of perforated sigmoid diverticulitis: highlighting the outcomes of laparoscopic lavage. *Dis Colon Rectum* 2010; **53:** 1537–41.

29 Kohl A, Rosenberg J, Bock D *et al.* Two-year results of the randomized clinical trial DILALA comparing laparoscopic lavage with resection as treatment for perforated diverticulitis. *Br J Surg* 2018; **105:** 1128–34.

30 Vandenbroucke JP, Von Elm E, Altman DG *et al.* Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *PLoS Med* 2007; **4:** e297.

31 Linder MM, Wacha H, Feldmann U, Wesch G, Streifensand RA, Gundlach E. [The Mannheim peritonitis index. An instrument for the intraoperative prognosis of peritonitis]. Der Mannheimer Peritonitis-Index. Ein Instrument zur intraoperativen Prognose der Peritonitis. *Chirurg* 1987; **58:** 84–92.

32 Vennix S, Morton DG, Hahnloser D, Lange JF, Bemelman WA, Research Committee of the European Society of Coloproctocology. Systematic review of evidence and consensus on diverticulitis: an analysis of national and international guidelines. *Colorectal Dis* 2014; **16:** 866–78.

33 Binda GA, Bonino MA, Siri G *et al.* Multicentre international trial of laparoscopic lavage for Hinchey III acute diverticulitis (LLO Study). *Br J Surg* 2018; **105:** 1835–43.

34 Vermeulen J, Gosselink MP, Busschbach JJ, Lange JF. Avoiding or reversing Hartmann's procedure provides improved quality of life after perforated diverticulitis. *J Gastrointest Surg* 2010; **14:** 651–7.

35 Banerjee S, Leather AJM, Rennie JA, Samano N, Gonzalez JG, Papagrigoriadis S. Feasibility and morbidity of reversal of Hartmann's. *Colorectal Dis* 2005; **7:** 454–9.

36 Kechagias A, Rautio T, Kechagias G, Mäkelä J. The role of C-reactive protein in the prediction of the clinical severity of acute diverticulitis. *Am Surg* 2014; **80:** 391–5.

37 Tursi A, Elisei W, Brandimarte G, Giorgetti GM, Aiello F. Predictive value of serologic markers of degree of histologic damage in acute uncomplicated colonic diverticulitis. *J Clin Gastroenterol* 2010; **44:** 702–6.

38 Shaikh FM, Stewart PM, Walsh SR, Davies RJ. Laparoscopic peritoneal lavage or surgical resection for acute perforated sigmoid diverticulitis: a systematic review and meta-analysis. *Int J Surg* 2017; **38:** 130–7.

39 Slim K, Le Roy B. Laparoscopic peritoneal lavage for perforated sigmoid diverticulitis – an example of surgical research failure. *Colorectal Dis* 2017; **19:** 208–208.

40 Vennix S, van Dieren S, Opmeer BC, Lange JF, Bemelman WA. Cost analysis of laparoscopic lavage compared with sigmoid resection for perforated diverticulitis in the Ladies trial. *Br J Surg* 2017; **104:** 62–8.

41 Gehrman J, Angenete E, Björholt I, Bock D, Rosenberg J, Haglind E. Health economic analysis of laparoscopic lavage versus Hartmann's procedure for diverticulitis in the randomized DILALA trial. *Br J Surg* 2016; **103:** 1539–47.

