ORIGINAL ARTICLE

Laparoscopic peritoneal lavage versus laparoscopic sigmoidectomy in complicated acute diverticulitis: a multicenter prospective observational study

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Abstract

Purpose Laparoscopic peritoneal lavage (LPL) is feasible in selected patients with pelvic abscess and generalized purulent peritonitis caused by acute diverticulitis. We aimed to compare LPL and laparoscopic sigmoidectomy (LS) in complicated acute diverticulitis.
Methods This prospective, observational, multicenter study included patients with a pelvic abscess not amenable to conservative management and patients with Hinchey III acute diverticulitis, from 2015 to 2018. Sixty-six patients were enrolled: 28 (42%) underwent LPL and 38 (58%) underwent LS. In LS, patients had a primary anastomosis, with or without ileostomy, or an end colostomy (HA). Major outcomes were mortality, morbidity, failure of source control, reoperation, length of stay, and diverticulitis recurrence.
Results Patient demographics were similar in the two groups. In LPL, ASA score > 2 and Mannheim Peritonitis Index were significantly higher ($p = 0.05$ and 0.004). In LS, 24 patients (63%) had a PA and 14 (37%) an HA. No death was recorded. Overall, morbidity was 33% in LPL and 18% in LS ($p = 0.169$). However, failure to achieve source control of the peritoneal infection and the need to return to the operating room were more frequent in LPL ($p = 0.002$ and $p = 0.006$). Mean postoperative length of stay was comparable ($p = 0.08$). Diverticular recurrence was significantly higher in LPL ($p = 0.003$).
Conclusion LPL is related to a higher reoperation rate, more frequent postoperative ongoing sepsis, and higher recurrence rates. Therefore, laparoscopic lavage for perforated diverticulitis carries a high risk of failure in daily practice.

Keywords Complicated acute diverticulitis · Laparoscopic lavage · Laparoscopic sigmoidectomy · Resection–anastomosis · Hartmann's procedure

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Introduction

Purulent peritonitis due to perforated acute sigmoid diverticulitis is a surgical challenge, traditionally managed with segmental resection and stoma formation. Although this approach remains the primary treatment option, alternative procedures have been proposed to decrease morbidity and the rate of permanent stoma of surgical therapy.

In the 1990s, laparoscopic peritoneal lavage (LPL) was proposed to treat patients affected by peritonitis due to acute perforated diverticulitis [1]. Despite promising results of initial retrospective and small-cohort studies [2, 3], three recent randomized trials comparing LPL to sigmoid resection for perforated diverticulitis have shown conflicting results. The LOLA arm of the Dutch LADIEs trial was prematurely interrupted because of an exceedingly high rate of complications in the LPL group [4]. The Scandinavian SCANDIV

study reported similar results; the authors therefore concluded that among patients with likely perforated diverticulitis undergoing emergency surgery, laparoscopic lavage versus primary resection did not reduce severe postoperative complications and led to worse outcomes in secondary endpoints [5]. However, Agenete et al. reported in their DILALA study that LPL is feasible and safe in short-term treatment for patients with Hinchey's III perforated diverticulitis [6].

In patients with generalized purulent peritonitis, another option is sigmoid resection and primary anastomosis (RPA) with or without diverting loop ileostomy [7]. This approach has the advantage of simultaneously treating intra-abdominal sepsis and diverticular disease with sigmoid resection followed by a colorectal anastomosis. Several studies have compared RPA versus Hartmann's procedure (HA), with conflicting results likely due to bias in patient recruitment [8]. Currently, several guidelines state that RPA in selected patients is a safe alternative to HA [9–11].

Although laparoscopic sigmoidectomy (LS) represents a more technically demanding procedure than open sigmoid resection, it could offer the advantage of reducing stress to critical patients affected by diverticular peritonitis. However, laparoscopy in such emergency settings could be accomplished only by experienced surgeons.

In this study, we focused on a selected cohort of patients presenting with complicated acute diverticulitis, in which LPL and LS were implemented. To our knowledge, this is the first study in which these two methods are compared.

The primary aim of the study was to evaluate which surgical strategy between LPL and LS could give better results in patients with modified Hinchey's grade II not responding to conservative therapy and grade III acute diverticulitis. The secondary aim was to compare RPA with or without diverting ileostomy versus HA, regarding short- and long-term outcomes within the LS group.

Given conflicting results and the absence of specific criteria for patient selection in other studies, we hypothesized that LPL presented a higher reoperation and abdominal sepsis control failure rate, increasing postoperative morbidity and mortality. We also hypothesized that, in case of LS, RPA was associated with better outcomes than HA.

Methods

This prospective, observational, multicenter, and international study was registered at ClinicalTrials.gov (NCT03008707) and was approved by the ethics committee in Pisa. Participating centers were in Italy, the UK, Greece, and Spain. A designated physician at each center entered patient data into a specifically designed database. The duration of this study was from 2015 to 2018.

Diagnosis of peritonitis from complicated diverticulitis was suspected at clinical examination and CT scan with the presence of abdominal fluid collection with or without free intra-peritoneal air and thickening of the left colon and sigma involved by diverticula. Written consent to participate was obtained from each patient.

Inclusion criteria were patients submitted to LPL or LS with or without anastomosis, for acute diverticulitis according to the modified Hinchey's classification [12] grade II not treatable by conservative treatment (antibiotics with or without percutaneous drainage), or classification grade III.

Exclusion criteria were septic shock, immunodepression, previous multiple surgical operations, Hinchey's grade I and IV, and extreme ages (< 15 and > 85 years).

Patients were classified by operative risk and severity of peritonitis according to the American Society of Anesthesiologists (ASA) score and the Mannheim Peritonitis Index (MPI) [13] (Fig. 1). Comorbidities were divided into cardiovascular disease, peripheral vascular disease, arterial hypertension, collagen-related disease, pulmonary disease, diabetes mellitus, and smoker status. Previous episodes of acute diverticulitis and previous abdominal surgical operations were also considered.

Primary endpoints of interests were reintervention rate, postoperative abdominal sepsis rate, short-term morbidity, and mortality. Postoperative abdominal sepsis rate was defined as the rate of patients with clinical and laboratory signs of sepsis with radiological evidence of abdominal ongoing infection requiring modification of antibiotic therapy, drains, or surgical operation. Morbidity was classified according to the Clavien and Dindo classification [14].

Secondary endpoints were mean operative time, conversion to laparotomy (with or without bowel resection), mean length of postoperative stay, incisional hernia rate, recurrent colonic diverticulitis rate, and stoma closure rate. All patients included in this study were followed up for 6 months from hospital discharge. Follow-up evaluation included irregular interval outpatient clinic visits and/or phone interviews.

Surgical techniques

The choice between the two approaches (LPL or LS) was left to the surgeon's preference after having evaluated the abdominal cavity and excluded the presence of fecal peritonitis.

Laparoscopic peritoneal lavage

Laparoscopic peritoneal lavage (LPL) began with induction of pneumoperitoneum using a Verress needle at the umbilicus or Hasson's open technique and CO_2 with an intraperitoneal pressure of 14 mmHg. Three trocars were used: a 10-mm

Fig. 1 The Mannheim Peritonitis Index

Risk Factors	Score
Age >50 years	5
Organ failure	7
Female sex	5
Malignancy	4
Preoperative duration of peritonitis more than 24 h	4
Origin of sepsis not colonic	4
Diffuse generalized peritonitis	6
Exudate	
Clear	0
Cloudy, Purulent	6
Fecal	12

Definition of Organ Failure	
Kidney failure	Creatinine level >177 mmol/L
	Urea level >167 mmol/L
	Oliguria <20 ml/h
Pulmonary insufficiency	pO2 <50 mmHg
	pCO2 >50 mmHg
Shock	Hypodynamic or hyperdynamic

trocar in the supra-umbilical area for advancing the laparoscope (30°, 10 mm), another 5-mm trocar in the right flank, and a further 5-mm trocar in the right iliac fossa.

Exploration of the peritoneal cavity was accurate and included a gentle blunt dissection of the inflamed sigmoid colon. Gross fecal finding in the cavity and/or identification of a bowel perforation was considered valid reasons to change strategy. Once the presence of the purulent collection in the peritoneal cavity was identified, a sample for bacteriological examination was taken and a complete evacuation was performed. Irrigation and suction with 3–6 L of warm saline were carried out until clear fluid was returned.

In case of dubious integrity of the colonic wall, an air test was performed to confirm the absence of leakage. The operation ended with an accurate revision of the hemostasis and the placement of two large silastic drains in the pelvis, respectively along the medial and lateral sides of the sigma.

Laparoscopic sigmoidectomy

Pneumoperitoneum was obtained as previously described. After placing a 12-mm trocar at the umbilicus, a 30°–10 mm laparoscope was introduced. Subsequently, three other trocars were positioned under vision: two 5-mm respectively in the left and the right flank and one 12 mm in the right iliac fossa. A careful exploration of the abdominal cavity was performed. Peritoneal adhesions were lysed if present.

The inferior mesenteric vein was dissected free below the inferior pancreatic margin, ligated with Hem-o-Lok® clips (Teleflex, Morrisville, NC, USA), and divided. A cautious mobilization from the left colonic flexure to the sigma, along with the Toldt's avascular plane, was then carried out with the help of radiofrequency or ultrasound devices. After the identification and preservation of the left ureter, the inferior mesenteric artery was clipped with Hem-o-Lok ® clips and then divided distally. In case of intense phlogosis, clipping of the artery could be performed distally from the origin of the left colic artery. The proximal rectum was then stapled and divided by using a laparoscopic articulated stapler. Resection was completed and the specimen delivered through a suprapubic wound-protected mini-laparotomy.

At this point, the decision to perform the HA or not was established by the surgeon according to patient's previous comorbidities (diabetes, immunosuppression, malnutrition, severe cardiac disease), hemodynamical status (septic shock requiring vasopressors), and the grade of perfusion of the two intestinal stumps. In case of anastomosis, a colorectal end-to-end or side-to-end mechanical anastomosis was performed.

A hydropneumatic test, or a test with trans-anal irrigation with blue of methylene-stained saline solution, was performed to rule out the presence of a leak of the suture line. Before wound closure, the pelvis was drained, and the creation of a protective ileostomy was decided case by case at the discretion of the surgeon.

Statistical analysis

Continuous data were presented as mean ± standard deviation unless indicated otherwise. Qualitative data were expressed as frequency and percentage. The Student's t test or Mann-Whitney U test, when data were not normally distributed,

was used to compare continuous quantitative data. Pearson's chi-square or Fisher's exact tests were used to compare categorical qualitative variables, where appropriate.

Primary outcome analysis was performed excluding patients in the LPL group who required a sigmoid resection and those where a protocol violation was assessed. Secondary outcomes were assessed without correction for multiple comparison. A p value < 0.05 was considered statistically significant. All analyses were carried out using XLSTAT software (Addinsoft, NY, USA).

Results

Patient characteristics

During the study period, 66 out of 216 patients (30.5%) undergoing surgery for perforated diverticulitis were enrolled. Patient demographics are summarized in Table 1. Among the overall cohort of patients, 28 (42.4%) underwent LPL and 38 (57.6%) had LS. No significant differences were found in terms of mean age ($p = 0.314$), gender distribution ($p = 0.07$), mean BMI ($p = 0.129$), previous episodes of diverticulitis ($p = 0.756$), or previous abdominal surgery ($p = 0.379$).

Significantly more patients with ASA score > 2 were found in LPL group (42.8% vs 21%; $p = 0.05$). Considering comorbidities, only arterial hypertension was significantly higher in the LPL group (60.7% vs 31.5%; $p = 0.018$). Mean value of C-reactive protein (mg/dL) was similar between the two groups ($p = 0.846$) (Table 1). Mean MPI was significantly higher in LPL group (17.82 ± 5.68 vs 13.56 ± 5.04; $p = 0.004$). The distribution of grades II and III according to the modified Hinchey's score was similar between the two groups, with a higher prevalence of grade III over grade II (53.6% vs 46.4% in LPL group; 57.9% vs 42.1% in LS group; $p = 0.727$).

Surgical procedures

LPL required a significantly shorter mean operative time than LS (76.74 ± 33.18 vs 225.36 ± 81.58; $p < 0.0001$) (Table 1). One patient in the LPL group required a conversion to open due to sigmoid ischemia, with a Hartmann's procedure warranted (Fig. 2). In five patients of the LS group (13.1%), the resection was performed after conversion to open ($p = 0.181$). The reasons for conversion included intolerance to pneumoperitoneum in three cases and tenacious adhesions in the remaining two patients. In the LS group, 24 patients (63%) had RPA, while the other 14 (37%) underwent resection with end colostomy (HA) (Fig. 3). In the subgroup of patients with RPA, five (20.8%) had a loop ileostomy.

Table 1 Patients' preoperative and intraoperative characteristics

|	Overall ($n = 66$)	LPL ($n = 28$)	LS ($n = 38$)	p value
Mean age (years) (SD)	57.19 (11.92)	59.25 (13.21)	55.68 (10.81)	0.314
Male gender (%)	39 (59)	13 (46.4)	26 (68.4)	0.07
Mean BMI (kg/m^2) (SD)	27.16 (4.37)	26.2 (3.33)	27.87 (4.94)	0.129
ASA score > 2 (%)	20 (30.3)	12 (42.8)	8 (21)	0.05
Previous diverticulitis (%)	25 (37.9)	10 (37.5)	15 (39.4)	0.756
Previous abdominal surgery (%)	22 (33.3)	11 (39.2)	11 (28.9)	0.379
Comorbidities (%)				
Cardiovascular disease	16 (24.2)	8 (28.5)	8 (21)	0.481
Peripheric vascular disease	9 (13.6)	4 (14.2)	5 (13.1)	0.895
Arterial hypertension	29 (43.9)	17 (60.7)	12 (31.5)	0.018
Collagen-related disease	7 (10.6)	4 (14.2)	3 (7.9)	0.405
Pulmonary disease	4 (6)	2 (7.1)	2 (5.2)	0.752
Diabetes mellitus	11 (16.6)	3 (10.7)	8 (21)	0.265
Smoker status	25 (37.9)	7 (25)	18 (47.3)	0.064
Mean C-reactive protein (mg/dL) (SD)	18.18 (12.65)	17.68 (12.9)	18.47 (12.7)	0.846
Mean Mannheim Peritonitis Index (SD)	15.2 (5.65)	17.82 (5.68)	13.56 (5.04)	0.004
Modified Hinchey's score				
Grade II (%)	29 (43.9)	13 (46.4)	16 (42.1)	0.727
Grade III (%)	37 (56.1)	15 (53.6)	22 (57.9)	
Mean operative time (min) (SD)	162.13 (98.19)	76.74 (33.18)	225.36(81.58)	< 0.0001
Conversion to open rate (%)	6 (9)	1 (3.5)	5 (13.1)	0.181
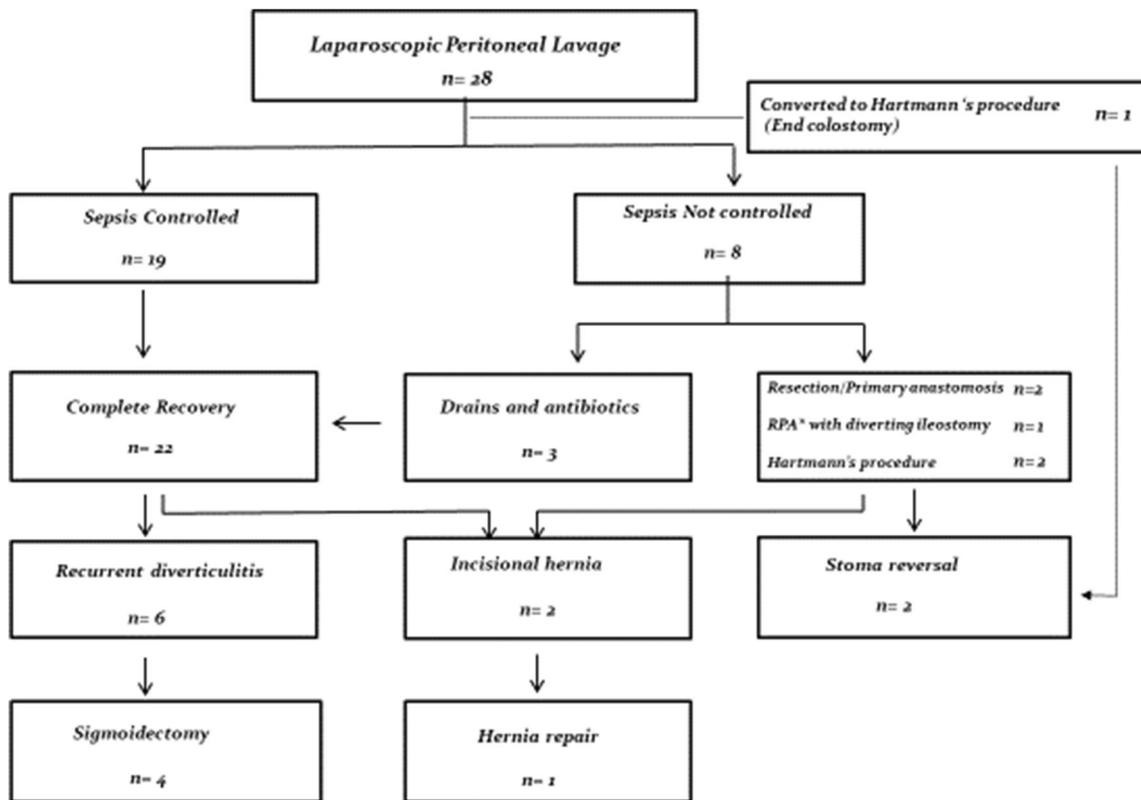
Fig. 2 Flowchart of patients with LPL

Postoperative findings

The LPL group showed a significantly higher postoperative abdominal sepsis rate (29.6% vs 2.6%; $p = 0.002$) (Table 2). Overall morbidity was 33.3% after LPL, and 18.4% after LS ($p = 0.169$).

Five patients (18.5%) in the LPL group required a reoperation during the postoperative hospital stay for the persistence of abdominal sepsis not amenable to conservative therapy. Of those patients, two had an open HA at postoperative day (POD) 5 and POD 9 respectively, two had RPA at POD 24 and POD 15 respectively (both were approached in laparoscopy, with one needing conversion to open for the presence of strong adhesions), and one underwent RPA with diverting ileostomy at POD 6 (Fig. 1).

Conversely, no reinterventions were performed following LS ($p = 0.006$). No deaths occurred in either group. Mean length of postoperative stay was slightly longer in the LPL group (11.4 vs 8.23 days; $p = 0.088$) (Table 2).

Follow-up

Late postoperative results after LPL and LS are summarized in Figs. 2 and 3, respectively. In the LPL group, six patients of 22 who had a complete recovery from the

procedure (27.3%) presented one or more episodes of recurrent diverticulitis during the follow-up. On average, recurrent diverticulitis appeared 5.25 months after primary surgery. During the period of follow-up, four of the six patients eventually required sigmoidectomy.

Two patients (7%) presented an incisional hernia. Two out of three patients who were discharged with a stoma in LPL group had their stoma closed during the follow-up; one presented a loop ileostomy and another an end colostomy (Fig. 2).

In the LS group, no recurrence of diverticulitis occurred during the follow-up (27.3% vs 0%; $p = 0.004$). Nine patients out of 38 (23.6%) presented an incisional hernia (7% vs 23.6%; $p = 0.10$). Fourteen out of 19 patients (74%) presenting a stoma had their ostomies reversed during the follow-up, and the remaining five patients had an end colostomy (Fig. 3).

Analysis of subgroups: comparison between HA and RPA in LS group

In the LS group, 24 patients (63%) were treated with RPA and 14 (37%) with HA. As shown in Table 3, there were no significant differences in terms of demographic and preoperative characteristics. RPA procedures were significantly longer than
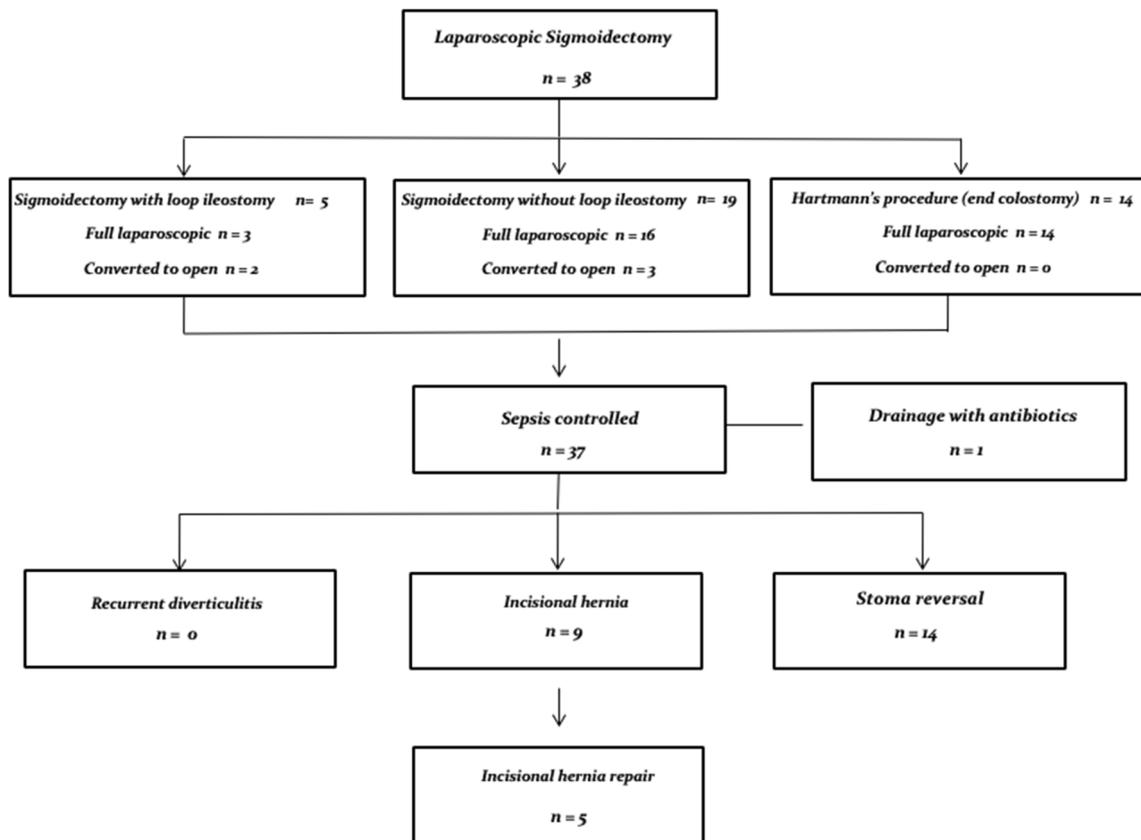
Fig. 3 Flowchart of patients with LS

HA (257.29 ± 77.65 vs 170.64 ± 56.29 min; $p = 0.001$). In five RPA patients, a conversion to open was necessary to complete the surgical operation. No HA required a conversion to open ($p = 0.067$). Postoperative abdominal sepsis rate was not significantly higher in the HA group compared to RPA (0% vs 7.1%; $p = 0.185$). No significant differences were found in overall morbidity, mean length of postoperative stay, or stoma closure rate (Table 3). Incisional hernia rate was significantly higher in the HA group (12.5% vs 42.8%; $p = 0.034$).

Discussion

In this study, we compared LPL versus LS in a selected cohort of patients affected by perforated acute diverticulitis. The findings demonstrate that LPL presents a high percentage of failure, and therefore, it should not be performed in daily clinical practice.

The role of LPL in perforated acute diverticulitis is still not clear. Consequently, its systematic use in clinical activity is yet under debate. LPL was conceived as a surgical approach to control diverticular sepsis without further operative management and to avoid a permanent stoma [15–17].

In recent years, there have been at least 10 systematic reviews with meta-analysis focusing on the role of LPL in acute perforated diverticulitis [15, 18–26]. The results were considerably different, likely due to the variability of the studies considered, the type of analysis performed, and the lack of specificity in the description of the evaluated outcomes. Most of the studies stated that LPL could be considered as an effective and safe approach for the treatment of Hinchey's III diverticulitis. A substantial drawback of the procedure is the risk of the patient developing an intra-abdominal abscess or infection that may ultimately lead to sigmoidectomy [15, 19–22, 26]. Nonetheless, only four studies concluded that LPL is not a safe approach for most patients presenting purulent diverticular peritonitis, because of the high rate of reoperations (30%) and the not insignificant risk of missing a sigmoid carcinoma (8–10%), although no significant differences were found in 30-day mortality [18, 23–25].

The main issue against LPL is the high same-admission reoperation rate. Our study showed an 18.5% rate of reoperation in the LPL group versus no reinterventions in LS group during the postoperative course. This proportion is slightly higher than results reported in the literature (13.1–14.6%) [24, 25]. Interestingly, we recognized the persistence of abdominal sepsis as the only reason for reoperation in LPL group. In all reoperations, a millimetric area of colonic perforation (not identified during the LPL) was detected. Even though all laparoscopic procedures were performed in centers

Table 2 Postoperative findings

	Overall ($n = 65$)	LPL ($n = 27$)	LS ($n = 38$)	p value
Postoperative abdominal sepsis rate (%)	9 (13.8)	8 (29.6)	1 (2.6)	0.002
Overall morbidity (%)	16 (24.2)	9 (33.3)	7 (18.4)	0.169
Grade I[a]	2 (3)	1 (3.7)	1 (2.6)	0.084
Grade II	5 (7.6)	1 (3.7)	4 (10.5)	
Grade IIIa	4 (6.1)	2 (7.4)	2 (5.2)	
Grade IIIb	5 (7.6)	5 (18.5)	0	
Grade IV	0	0	0	
Reoperation rate (%)	5 (7.6)	5 (18.5)	0	0.006
Mortality (%)	0	0	0	1
Mean length of postoperative stay (days) (SD)	9.46 (7.36)	11.4 (9.60)	8.23 (5.21)	0.088

[a] According to Clavien and Dindo Classification

experienced in minimally invasive surgery, this finding raises the question whether LPL can be useful in recognizing the colonic perforation responsible of the intra-abdominal sepsis.

In the SCANDIV randomized study, Schultz et al. found a 20% rate of same-admission reoperation. They stated that extensive dissection of inflammatory adhesions to the sigmoid colon during the laparoscopic lavage procedure might unfold small sealed perforations or, conversely, conceal larger defects in the colon [5]. Binda et al. demonstrated that extensive adhesiolysis, together with a high ASA grade and MPI scores, and absence of previous diverticulitis, were associated with increased failure rates [17].

Our multicentric study put no specific limits on dissection of adhesions during the laparoscopic lavage. The high reoperation rate identified in this study could be related to the last factor. However, several other reasons leading to reoperation

have been described in the literature. A multicentric study by Catry et al. [27] compared 15 LPL versus 25 RPA: 40% of LPL patients required reoperation for peritonitis in 26.6%, intra-abdominal abscess in 7%, ileus in 7%, intra-abdominal hemorrhage in 13.3%, and wound infections in the remaining 7%. For these reasons, the authors concluded LPL is associated with a high risk of failure in daily practice, and consequently, RPA should be the primary option for treating purulent diverticular peritonitis. Other reported reasons for reoperation after LPL were retaining of drainage [6] and wound dehiscence [4].

In the current study, a postoperative abdominal ongoing sepsis rate of 29.6% in the LPL group and 2.6% in the LS group was identified. In their review, Shaikh et al. reported a 28.9% rate of postoperative intra-abdominal abscess following LPL versus 8.7% after sigmoid resection, which was

Table 3 Comparison between RPA and HA in LS group

	RPA ($n = 24$)	HA ($n = 14$)	p value
Mean age (years) (SD)	56.75 (10.84)	53.85 (10.92)	0.434
Male gender (%)	17 (70.3)	9 (64.2)	0.645
Mean BMI (kg/m^2) (SD)	27.05 (5.12)	29.22 (4.49)	0.200
ASA score > 2 (%)	4 (16.7)	4 (28.5)	0.385
Previous diverticulitis (%)	12 (50)	3 (21.4)	0.101
Previous abdominal surgery (%)	5 (20.8)	6 (42.8)	0.266
Mean C-reactive protein (mg/dL) (SD)	15.52 (10.15)	23.39 (15.3)	0.09
Mean Mannheim Peritonitis Index (SD)	13.73 (5.14)	13.28 (5.06)	0.702
Modified Hinchey's score			
Grade II (%)	11 (45.8)	5 (35.7)	0.788
Grade III (%)	13 (54.2)	9 (64.3)	
Mean operative time (min) (SD)	257.29 (77.65)	170.64 (56.29)	0.001
Conversion to open rate (%)	5 (20.8)	0	0.067
Postoperative abdominal sepsis rate (%)	0	1 (7.14)	0.185
Overall morbidity (%)	5 (20.8)	2 (14.3)	0.615
Mean length of postoperative stay (days) (SD)	8.62 (4.62)	7.57 (6.22)	0.555
Stoma closure rate (%)	4/5 (80)	10 (71.4)	0.827
Incisional hernia rate (%)	3 (12.5)	6 (42.8)	0.034

statistically significant ($p = 0.0004$) [26]. As stated earlier, most intraoperative abscesses are treated with a surgical operation. However, in some circumstances, the ongoing sepsis could be resolved by using a percutaneous drain [4, 5, 26].

In our study, three patients with postoperative pelvic abscesses following LPL were treated with percutaneous drains and narrow-spectrum antibiotics; interestingly, none required surgical resection during follow-up. Conversely, one patient in the LS group who had HA required a percutaneous drain along with antibiotic therapy. Nonetheless, we believe that this conservative procedure is not safe, because in some circumstances, it could lead septic patients to dangerous clinical consequences and not resolve the real cause of infection: the colonic perforation. Percutaneous drainage should not be considered after LPL failure in controlling abdominal sepsis. A randomized multicentric study should be carried out to further investigate this, although we acknowledge that it could raise critical ethical problems.

As already shown in several studies [4–6], we found no significant differences in short-term morbidity and mortality between the two arms. However, the overall morbidity in LPL was higher than in LS (33.3% vs 18.4%; $p = 0.169$) and was mainly represented by major complications (Clavien and Dindo grade > II: seven out of nine patients) Table 2.

The overall complication rate in the current study is in line with data reported in the literature [17]. Despite this, none of the patients were referred to an intensive care unit for ongoing management of complications. Nevertheless, this finding may represent a further unfavorable aspect of LPL compared to resection. Even though this study considered only patients who underwent LS, LPL presents an increased incidence of adverse events during the first 30 postoperative days in all comparative studies [27]. Conversely, the LS group had a higher rate of minor complications (Clavien and Dindo grade ≤ II: five out of seven patients). The overall higher rate of postoperative complications in the LPL group determined a longer mean length of postoperative stay, even though it was not statistically significant (LPL 11.4 vs LS 8.23 days; $p = 0.08$) (Table 2). Interestingly, in this study, perioperative and follow-up mortality was nil in both arms.

In the recent meta-analysis by Penna et al. that focused on studies comparing LPL with colonic resections for acute perforated diverticulitis, 30-day, 90-day, and 1-year mortality following LPL were 3.3%, 3.6%, and 6.5%, respectively. Similar rates were shown after colonic resections (3.9%, 5.7%, and 11.6% respectively) and consequently, results were not significantly different [25].

Most of the considered studies compared LPL with open resections, and there was no standardization of the techniques used for the sigmoidectomy. Our findings could therefore be related to a bias in selection of healthier patients. However, as shown in Table 1, 42.8% of LPL patients and 21% of LS patients presented an ASA score higher than 2, indicating that they were affected by severe comorbidity or clinically compromised. The latter finding is also confirmed by the mean MPI being significantly higher in the LPL group than the LS group (17.82 vs 13.56; $p = 0.004$).

In agreement with Schultz et al. [28], data from follow-up of our series demonstrate that complications and reinterventions after LPL were mainly related to diverticular recurrence, which occurred in six out of 25 patients (24%). Four required a sigmoidectomy with primary anastomosis.

LPL has been also proposed as a bridge procedure to elective sigmoid resection [15]. From this perspective, LPL would reduce peritoneal contamination, allowing patients to receive a second-step low-risk RPA. Unfortunately, this role of LPL has been poorly investigated. In contrast, most complications after primary resection were related to an incisional hernia (nine out of 38) and stoma formation (in 19 patients) rather than to the primary disease. Reoperations in this group consisted mainly of stoma reversals (14 out of 19) and hernia repair (five out of nine). More than one third of patients in the resection group had a stoma (end colostomy) 6 months after surgery, which may be related to frailty in this population.

In this study, 38 patients underwent LS for acute perforated diverticulitis. These cases represent a considerable cohort of patients for a comparison between two different strategies that can be adopted in diverticular emergency settings: HA and RPA. We reported 24 RPA (63%) and 14 HA (27%).

To our knowledge, no studies focusing only on the laparoscopic colonic resection in emergency settings for complicated acute diverticulitis have been published. Recently, Desay et al. reported on 37 patients with sigmoid diverticulitis managed laparoscopically: 22 were performed in emergency and 26 were complicated diverticulitis. Of the overall group, 18 underwent laparoscopic RPA without stoma, 11 patients had RPA with stoma, six had HA, and two had laparoscopic lavage. The authors demonstrated neither anastomosis-related complications nor other relevant morbidities, concluding that the laparoscopic management of diverticulitis is feasible and safe and should be the surgical procedure of choice in emergency settings for simple or complicated diverticulitis [29]. Indeed, this cohort of patients is very small to draw definitive conclusions. However, only one of the three important randomized studies comparing HA with RPA considered both open and laparoscopic operations. Binda reported a rate of open vs laparoscopic surgery of 88.2% vs 11.8% in RPA and 94.6 vs 5.4% in HA [30].

Analyzing the overall outcomes, we found comparable morbidity and postoperative sepsis rates in RPA and HA groups. These results are consistent with those of the three trials published previously. As previously highlighted, mortality was nil. Interestingly, the stoma closure rate during the follow-up was not significantly different between RPA and HA (80% vs 71.4%). The latter finding is not in line with data

reported in the literature, as the rate of stoma closure has been reported as significantly higher in RPA with diverting ileostomy compared to patients who underwent HA [7, 30, 31]. This may be because, although there is the evidence that stoma reversal in HA presents higher rates of major complications and mortality [32], the lower mean age (53.85 years) and low rate of multiple severe comorbidities (ASA > 2 in only 28.5% of cases) in HA were factors motivating surgeons to perform the reversal.

Another result emerging from this study is the higher rate of conversion to open in RPA group. Undeniably, this finding could be explained by the fact that RPA is more technically challenging than HA, mainly in an emergency setting like perforated diverticulitis. However, we would like to highlight that experienced surgeons performed all surgical procedures in this study. From these series, it appears that patients undergoing HA present a significantly higher incisional hernia rate (12.5% vs 42.8%). It is difficult to give a reason for this finding. As reported by Timmermans et al. [33], we can speculate that patients with an intraperitoneal end ostomy are more likely to present an incisional hernia. However, as the study cohort is relatively small, further studies are required to confirm this hypothesis.

To the authors' knowledge, the present study is the only one focusing on the comparison between laparoscopic lavage and laparoscopic colonic resection in perforated diverticulitis. An additional strength of this study could paradoxically be its multicenter and observational feature, without defined protocols, which shows the realistic procedures of surgeons in such situations. However, we acknowledge several limitations. The most important is the lack of randomization that could have overcome the selection bias among patients with perforated purulent diverticulitis undergoing LPL and LS. The observational design of the study could have influenced the results, and consequently, the presented results cannot be conclusive. Although this study was conceived as randomized, several organizational and financial problems with the ethical committee and the local health system ultimately made randomization prohibitive. The decision to perform LPL or LS was left to the attending surgeon intraoperatively, which may represent an important source of selection bias. However, all surgical operations were performed by experienced surgeons, who were able to complete both procedures at the same level. Another possible limitation is the absence of a defined technical protocol for LPL that could have homogenized the extension of the adhesiolysis and the quantity of saline used for the lavage.

Conclusions

In spite of its observational and small-cohort nature, this study demonstrates that LPL for Hinchey's grades III and II not treatable with conservative therapy diverticulitis is related to a higher reoperation rate, more frequent postoperative ongoing sepsis, and higher recurrence rates, making this procedure a high risk of failure in daily practice. LS is a safer and more effective procedure that permits an adequate control of source infection in the hands of experienced surgeons. In the case of resection, RPA with or without diverting ileostomy could be the optimal option. A randomized study is needed for definitive results.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest. The present study has been presented as oral communication at the American College of Surgeons 105th Annual Clinical Congress, Scientific Forum, San Francisco (CA), United States of America

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (Comitato Etico di Area Vasta Nord Ovest, CEAVNO, prot. N 890/2015) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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