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Original article

Cost analysis of laparoscopic lavage compared with sigmoid resection for perforated diverticulitis in the Ladies trial

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Background: **Laparoscopic peritoneal lavage is an alternative to sigmoid resection in selected patients presenting with purulent peritonitis from perforated diverticulitis. Although recent trials have lacked superiority for lavage in terms of morbidity, mortality was not compromised, and beneficial secondary outcomes were shown. These included shorter duration of surgery, less stoma formation and less surgical reintervention (including stoma reversal) for laparoscopic lavage *versus* sigmoid resection respectively. The cost analysis of laparoscopic lavage for perforated diverticulitis in the Ladies RCT was assessed in the present study.**

Methods: **This study involved an economic evaluation of the randomized LOLA (LaparOscopic LAvage) arm of the Ladies trial (comparing laparoscopic lavage with sigmoid resection in patients with purulent peritonitis due to perforated diverticulitis). The actual resource use per individual patient was documented prospectively and analysed (according to intention-to-treat) for up to 1 year after randomization.**

Results: **Eighty-eight patients were randomized to either laparoscopic lavage (46) or sigmoid resection (42). The total medical costs for lavage were lower (mean difference €−3512, 95 per cent bias-corrected and accelerated c.i. −16 020 to 8149). Surgical reintervention increased costs in the lavage group, whereas stoma reversal increased costs in the sigmoid resection group. Differences in favour of laparoscopy were robust when costs were varied by ±20 per cent in a sensitivity analysis (mean cost difference €−2509 to −4438).**

Conclusion: **Laparoscopic lavage for perforated diverticulitis is more cost-effective than sigmoid resection.**

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Introduction

Diverticular disease is one of the most costly gastrointestinal disorders, with an estimated incidence of 1·85 per 100 000 population per year for purulent peritonitis from perforated diverticulitis[1–3]. Case series have shown laparoscopic peritoneal lavage as a promising alternative for sigmoid resection in patients with purulent peritonitis due to perforated diverticulitis. This non-resectional strategy was first described in 1996 and developed further in 2008[4,5]. A systematic review of case series showed a mortality rate of less than 5 per cent, and a colostomy was avoided in the majority of patients[6]. However, prospective studies[7–9] have not been able to reproduce all advantages in a randomized setting. In these trials, laparoscopic lavage did not result in a reduction of morbidity, although mortality was better or similar. The shorter duration of surgery, reduction of stoma formation and lower associated costs may benefit patients managed with laparoscopic lavage alone. An economic evaluation of laparoscopic lavage compared with sigmoid resection based on patients in the LOLA (LaparOscopic LAvage) arm of the Ladies trial was undertaken and the findings are presented here.

Methods

This economic evaluation was conducted as part of the Ladies trial, a randomized open-label multicentre trial comparing laparoscopic lavage with sigmoid resection for perforated diverticulitis. Details of the design, conduct and

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clinical findings have been reported elsewhere[7,10]. In brief, patients with suspected perforated diverticulitis, clinical signs of general peritonitis and radiological findings of diffuse free intraperitoneal air or fluid were eligible for inclusion. Patients with Hinchey IV peritonitis or overt perforation could be included only in the DIVA (perforated DIVerticulitis: sigmoid resection with or without Anastomosis) arm. The DIVA arm is ongoing, whereas this laparoscopic lavage (LOLA) arm was terminated early at the planned interim analysis. At that time, 88 patients with purulent peritonitis were included in the LOLA arm.

The study protocol was approved by the ethical review board, and written informed consent was obtained from all patients before randomization. This study was investigator-initiated and designed in accordance with the declaration of Helsinki and good clinical practice guidelines. The study is registered with ClinicalTrials.gov (NCT 01317485), and the original study protocol includes the economic evaluation presented here[10].

Economic evaluation

The planned economic evaluation in the protocol estimated the costs and cost-effectiveness of laparoscopic lavage *versus* sigmoid resection for up to 12 months after randomization from a societal perspective in the Netherlands. Health outcomes in the cost-effectiveness analysis were major morbidity and mortality up to 12 months and quality-adjusted life-years (QALYs) at 12 months. As no difference was shown for either primary clinical outcome or QALYs between groups in the primary paper[7], a cost-effectiveness or cost-utility analysis could not provide any useful information and is not presented in this paper; however, details can be found in *Appendix S1* (supporting information).

A model-based analysis was planned to extrapolate the results of lavage and estimate the cost for both treatment options in the long term. Dutch government 2012 tables were used to estimate the remaining life expectancy at the time of surgery, and to calculate the costs for the remaining years of life after the end of follow-up at 12 months[11]. The costs were weighted by the probabilities of occurrence in a decision-tree model. The probability of stoma reversal beyond 12 months was estimated at 30 per cent for those alive with a stoma, with a success rate of 93 per cent and a mortality rate of 1 per cent[12]. The rate of readmission for recurrent diverticulitis beyond 12 months was estimated at 35 per cent of patients in whom the sigmoid remained *in situ*, with a subsequent risk of elective sigmoid resection of 15 per cent[13,14]. The risk of abdominal wall hernia requiring surgical repair is estimated at 21 per 1000 patient-years for laparoscopic procedures and 39 per 1000 patient-years for open colonic surgery[15]. The robustness of these estimates was tested by varying the risks in one-way sensitivity analyses.

A *post hoc* sensitivity analysis of indirect non-medical costs, owing to absence from paid work, was performed because only a minority of the included patients had paid employment at the time of randomization. Thus, the group of patients aged less than 60 years was used according to the stratification during randomization as a subgroup for this analysis. Although the official age for retirement in the Netherlands was 65 years at the time of randomization, it was then still common to retire at age 60 years, and only six of 53 patients aged over 60 years had a paid job.

Resource utilization

Healthcare utilization and use of other resources were documented prospectively for individual patients according to the predefined protocol[10]. Resource use was documented within the study clinical record forms or retrieved from the regular questionnaire responses. There was no additional study-related resource use or costs. Data for resource utilization included direct medical costs: the primary hospital admission (such as ward and ICU stay) and primary surgery; all additional procedures including surgical reinterventions and percutaneous interventions; additional diagnostic imaging (for example diagnostic plain X-rays and CT); readmissions; stoma care, stoma reversal surgery and related hospital admission; outpatient consultation visits (with surgeon, gastroenterologist, general practitioner, physiotherapist or company physician); and formal home care (assistance with household tasks, personal care or nursing). Direct non-medical costs included out-of-pocket costs for travel expenses and informal home care. Direct medical and non-medical resource use was documented in patient-reported questionnaires at 1, 3, 6, 9 and 12 months.

Indirect non-medical costs as a result of absence from paid work or lowered productivity while at work were determined using the Health and Labour Questionnaire[16] at 1, 3, 6, 9 and 12 months. The friction costs method was used to estimate the duration of lost productivity, with age-adjusted average daily wages based on the Dutch guideline[17]. The EuroQol – 5D (EQ-5D™; EuroQol Group, Rotterdam, The Netherlands) questionnaire, valued to the Dutch tariff, was converted to QALYs using the area under the curve method. As QALYs were measured at 2 weeks, 4 weeks, 3 months and 6 months after surgery, the 6-month data were extrapolated to 12 months.

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Table 1 Unit costs for major resources used

	Costs (€)	Unit
Laparoscopic lavage	2056·63	Procedure
Hartmann's procedure*	2847·84	Procedure
Primary anastomosis	3437·23	Procedure
Surgical ward	485·43	Day
ICU	2318·80	Day
Ileostomy reversal	2464·75	Procedure
Colostomy reversal	3694·05	Procedure
Percutaneous drainage	161·85	Procedure
Acute relaparotomy	3226·77	Procedure
Elective sigmoid resection	3960·50	Procedure
Incisional hernia repair	1211·15	Procedure

Mean calculated costs per patient, based on individual patient data, indexed for 2012. *Non-restorative sigmoid resection.

Unit costs

Estimates of unit costs were derived from several different sources: the Dutch guideline on unit costing in healthcare[17]; the Hospital Costs ledger 2012 from the Academic Medical Centre (AMC), Amsterdam, based on top-down cost calculations; and separate bottom-up cost calculations within the AMC for the costs of the index surgical procedures. These bottom-up calculations were performed for laparoscopic lavage and laparoscopic and open sigmoid resection with and without primary anastomosis. Procedure costs included costs for all reusable instruments and disposables, and costs for personnel and overhead per time unit. For the sigmoid resection group, mean costs for each randomized patient were calculated based on the actual ratio of these different possible procedures, such as open and laparoscopic surgery and colostomy, ileostomy, or none. All costs were expressed in euros and inflated when necessary to 2012, using the price index rate for the Dutch healthcare sector (*Table 1* for summary and *Table S1* (supporting information) for full details). If different unit costs were available for academic and non-academic hospitals, each was applied to the respective patients.

Power calculation

The LOLA arm of the Ladies trial was powered on the primary clinical outcome with a sample size of 264. The mean(s.d.) costs for the sigmoid resection group were estimated at €28 000(21 000) in the first year[18]. At the time of study design, it was assumed there would be a low rate of reintervention, with the lack of stoma reversal and associated costs in the lavage group. Therefore, the cost of lavage was estimated at approximately €18 000 in the first year. With the present sample size of 88 patients, a power of 0·73 could be achieved. A minimum cost reduction of €9000 would be required to achieve a power above 0·80.

Table 2 Baseline characteristics and clinical outcomes

	Laparoscopic lavage ($n = 46$)	Sigmoid resection ($n = 42$)
Age (years)*	62·3(12·7)	64·0(12·3)
Sex ratio (M : F)	26 : 20	25 : 17
BMI (kg/m^2)*	27·6(6·2)	27·0(4·4)
Duration of surgery (min)†	60 (48–82)	120 (99–150)
Laparoscopic lavage	45	1
Hartmann's procedure	1	21
Primary anastomosis	0	20
Remaining life expectancy (years)*	22·3(10·5)	21·7(9·5)

Values are *mean(s.d.) and †median (i.q.r.).

Any increase in the standard deviation would reduce the power further.

Statistical analysis

Resource use per patient was multiplied by unit costs, and total costs per patient were calculated. Mean resource use and mean costs per patient for the two groups were reported. Data are reported as mean(s.d.), median (i.q.r.), or number with percentage of the group as appropriate. As most volumes of resource utilization follow a skewed distribution, 95 per cent confidence intervals around the differences in mean costs were calculated by bias-corrected and accelerated (BCaCI) bootstrapping. Bootstrapping generates multiple replications of the statistic of interest by sampling (1000 samples) with replacement from the original data[19].

Robustness of the results for uncertainty in the assumptions and estimates was evaluated in sensitivity analyses, by varying unit costs for pertinent volumes of healthcare utilization and a subgroup analysis based on age.

All analyses were performed for the randomized groups according to the intention-to-treat principle, with costs calculated for the procedure actually performed. Analyses were done using SPSS® version 22·0 software (IBM, Armonk, New York, USA) and R version 2·13.1 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Between 1 July 2010 and 22 February 2013, a total of 88 patients were randomized and analysed in the LOLA arm of the Ladies trial; there were 46 patients in the laparoscopic lavage and 42 in the sigmoid resection group (20 sigmoid resection with end colostomy and 22 sigmoid resection with primary anastomosis, of whom 14 had a diverting ileostomy). All 88 randomized patients were included in the cost analysis. Baseline characteristics are

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Table 3 Resource utilization and mean costs per patient, indexed for 2012

		Laparoscopic lavage ($n = 46$)		Sigmoid resection ($n = 42$)		
	Unit	Mean units	Mean costs (€)	Mean units	Mean costs (€)	Cost difference (€)
Index admission						
Index surgery	Procedure	1·0	2074	1·0	3110	
Surgical ward	Days	12·7	7370	12·9	7517	
ICU	Days	2·5	5505	2·8	6185	
Additional imaging	Test	3·0	293	2·9	213	
Subtotal			15 276		17 111	−1834 (−13 866, 7976)
Readmission and reinterventions						
Acute reinterventions	Procedure	0·7	1170	0·2	628	
Elective reinterventions	Procedure	0·3	974	0·2	190	
Readmission ward	Day	7·4	4343	5·4	2899	
Readmission ICU	Day	0·1	285	0·1	156	
Subtotal			6786		3873	2912 (−478, 6355)
Stoma-related costs						
Stoma care	Day	19·1	1019	89·2	2655	
Reversal surgery	Procedure	0·1	396	0·5	1806	
Reversal ward admission	Day	0·7	355	3·5	2025	
Subtotal			1769		6590	−4821 (−7409, −2560)
Other						
Imaging	Unit	0·8	89	0·7	108	
Consultations and travel	Visit	4·6	352	5·3	363	
Home and informal care	Hour	57·7	1257	46·6	950	
Total medical costs			25 393		28 905	−3512 (−16 020, 8149)
Indirect non-medical costs	Hour	54·3	1731	141·8	4520	−2789 (−2789, 1810)
Total costs (12 months)			27 125		33 425	−6300 (−18 804, 6546)

Values in parentheses are 95 per cent bias-corrected and accelerated confidence intervals. Some smaller cost groups are not shown (transfusion, consultations in the emergency room, general practitioner and outpatient clinic, travel expenses, separate home and informal care costs), but are included in subtotal and total costs.

presented in *Table 2*. For the Health and Labour Questionnaire, used to determine production losses, the response rate was 55 (64 per cent) of 86 patients alive at 2 weeks, and 49 (63 per cent) of 78 patients alive at 12 months. Some 69 patients (78 per cent) completed at least one of the questionnaires.

A summary of mean costs per patient per group, including mean differences, is shown in *Table 3*. During the index admission, a trend for lower costs for lavage was seen (mean difference (MD) € − 1834, 95 per cent BCaCI −13 866 to 7976), and the costs of stoma care and stoma reversal were lower by € − 4821 (−7409 to −2560) in the lavage group. Costs for reintervention in the lavage group showed a trend for higher costs by €2912 (−478 to 6355). Together, this resulted in total medical costs for the 12-month study of €25 393 per patient in the lavage group and €28 905 per patient in the sigmoid resection group (MD € − 3512, −16 020 to 8149). A small proportion of patients contributed to the majority of the costs. The 10 per cent most costly patients contributed 33 per cent of the total costs, caused mostly by their prolonged hospital and ICU stay.

Long-term costs were calculated for the period from 12 months after surgery to the end of life, which was calculated as a mean of 22 months additional survival per patient alive (*Table 2*). Six patients in each group had a colostomy beyond 12 months, and costs were estimated at €82 359 and €95 592 per patient with a stoma for their remaining life, for the lavage and sigmoid resection group respectively. In addition, the risk of recurrent diverticulitis (35 per cent for patients without sigmoid resection, 5 per cent for those who had sigmoid resection) and subsequent elective sigmoid resection and the risk of hernia surgery was taken into account. This resulted in an additional €13 884 for the lavage group and €18 133 for the sigmoid resection group for patients alive, with total medical costs to the end of life of €38 070 and €44 448 per patient respectively (MD € − 6377, 95 per cent BCaCI −26 221 to 12 175). The estimated medical costs per subgroup, for follow-up from 12 months to estimated end-of-life per patient, are shown in *Table S2* (supporting information).

Sensitivity analyses

Sensitivity analysis was used to account for the uncertainty around the calculated costs. Costs are known to vary between hospitals and countries, and thus major costs varied by ±20 per cent for both groups. For index procedure

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Table 4 Sensitivity analysis of medical costs

	Laparoscopic lavage (€)	Sigmoid resection (€)	Cost difference (€)
Base analysis	25 393	28 905	−3512 (−16 020, 8149)
Index surgery			
−50%	24 308	27 264	−2956 (−18 370, 9191)
+50%	27 382	31 374	−3992 (−19 244, 8153)
Hospital stay (ward, ICU)			
−20%	22 998	26 286	−3288 (−16 020, 7393)
+20%	28 262	31 871	−3609 (−21 010, 10 523)
Stoma-associated costs			
−20%	24 991	27 501	−2509 (−17 572, 9410)
+20%	25 699	30 137	−4438 (−19 645, 8041)
Acute or elective relaparotomy			
−20%	24 916	28 655	−3739 (−18 580, 8246)
+20%	25 774	28 983	−3209 (−18 820, 9109)

Costs for individual cost groups are increased or decreased by the specified percentage; all other cost groups remained constant. Values in parentheses are 95 per cent bias-corrected and accelerated confidence intervals.

costs, ±50 per cent was used as these costs in particular tend to vary between hospitals. The total cost difference of these sensitivity analyses varied between € − 2509 and −4438 in favour of laparoscopic lavage, demonstrating consistently higher costs associated with sigmoid resection (*Table 4*).

The impact of production losses on overall costs was limited as, owing to their age, only a minority of the included patients had paid employment. When calculating production losses for the group of patients aged less than 60 years (lavage, 17; resection, 16), the losses were greater in the resection group (lavage €2578 *versus* resection €11 230; MD € − 8652, 95 per cent BCaCI −17 879 to −1448), contributing to further reduction of the total costs at 1 year in the lavage group (€24 612 *versus* €36 239 in the resection group; MD € − 11 627, −27 573 to 6706).

Discussion

Although laparoscopic lavage was not superior to sigmoid resection with regard to the primary clinical outcome (morbidity), beneficial secondary outcomes have been shown[7]. These secondary outcomes include shorter duration of surgery (60 *versus* 120 min), lower rate of stoma formation (26 *versus* 81 per cent), and higher number of patients with no surgical reintervention (including stoma reversal) (57 *versus* 36 per cent) for laparoscopic lavage and sigmoid resection respectively. In three-quarters of the patients, laparoscopic lavage was successful in controlling the abdominal sepsis, and these patients did not require acute surgical reintervention. Although these reinterventions accounted for an increased postoperative morbidity rate in the lavage group, a similar rate of other adverse events occurred and median postoperative hospital stay was shorter (8 days for lavage *versus* 10 days for sigmoid resection). The postoperative mortality rate was low in both groups (2 of 46 patients in the lavage group and 1 of 42 in the sigmoid resection group), such that statistical comparison was not possible.

From the present clinical data for up to 12 months after surgery, it can only be hypothesized whether or not the avoidance of acute sigmoid resection is of benefit. By avoiding acute resection, most late colectomy operations could be performed laparoscopically and with primary anastomosis without loop ileostomy. Thus, quality of life is maintained, additional stoma reversal surgery is avoided, and the risk of abdominal wall hernia is reduced by avoiding laparotomy[20]. For most patients, elective sigmoid resection has a similar morbidity risk and similar length of hospital stay compared with end colostomy reversal[21,22].

The cost differences per cost group (such as index surgery, readmissions and reinterventions, stoma-related costs) are in line with the clinical outcomes reported previously[7]. Some factors reduce costs, such as shorter duration of surgery, whereas others increase costs. Increased costs were found in the lavage group as a result of surgical reintervention, whereas stoma care, productivity losses and stoma reversal surgery were costly following sigmoid resection. Postoperative hospital ward stay was the single highest cost, approximately €7500 for both groups.

As stoma costs contribute strongly to the increased costs in the resection group, it is important to note that 50 per cent (21 of 42) of these patients had a Hartmann procedure and 48 per cent (20 of 42) had a primary anastomosis, as randomized within the ongoing DIVA part of the trial. Based on the data from non-included patients, about 65 per cent of patients would undergo Hartmann's procedure, 15 per cent primary anastomosis and 20 per cent lavage. With these proportions, cost would be even more in favour of lavage owing to the high stoma-associated costs. However, if the hypothesis of the DIVA arm is true and stoma-free survival for patients in the primary anastomosis group is increased with equal or improved morbidity rates, the cost reduction for lavage might even disappear.

These calculations have been performed for a 12-month follow-up in the Ladies trial, and were extrapolated to end of life. Stoma-related costs were the highest for the remaining follow-up, at more than €80 000 per patient with a colostomy. Therefore, the number of non-reversed stomas per group is of major influence to the total costs, much higher than the costs associated with recurrence, elective

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sigmoid resection and hernia surgery. Although a significant proportion of patients with a Hartmann procedure never have a reversal, the stoma remains a source of expense throughout the life of these patients[23]. As 50 per cent of patients having lavage in the LOLA arm underwent sigmoid resection within the first year, the other 50 per cent remain at risk of recurrence and resection in subsequent years[7]. Despite the fact that the present study protocol dictated elective surgery only in symptomatic patients, several patients had prophylactic elective surgery as a result of national guidelines and local practice. If current practice guidelines were implemented fully, a lower rate of sigmoid resection should be achievable. In the series by Myers and colleagues[5], none of the initially successfully managed patients required elective sigmoid resection for recurrent diverticulitis, and only two of 88 were readmitted owing to recurrence. Overall, this rate was reported as 38 per cent in the meta-analysis presented in the supplemental data of the LOLA publication[7], but varied between 0 and 100 per cent as some authors performed routine resection. When series reporting 0 or 100 per cent were excluded, a sigmoid resection rate of 54 per cent was found, but less than half of the studies reported the length of follow-up and time to resection.

An important limitation of this study is that all cost and resource calculations were based on the Dutch healthcare system, where the fixed reimbursement tariff for diverticulitis does not depend on actual procedures performed. Only a small number of patients were included in the Belgian and Italian hospitals, such that reliable costs could not be estimated. To allow international interpretation, a sensitivity analysis for all important subgroups of costs was performed by varying the unit costs of each subgroup by −20/50 to +20/50 per cent. Although none of the calculated total costs was significantly different between the two groups, there was a robust reduction in costs for laparoscopic lavage across all analyses. As the study was terminated early, at just over 30 per cent of the originally calculated sample size, the power was insufficient to show a robust statistically significant result. Although the accrual rate of 34 per cent might have introduced selection bias, no differences in baseline were found for included and non-included patients, so selection bias is not apparent[7].

Another important limitation was the lack of quality control for laparoscopic lavage. When designing the study, laparoscopic lavage was assumed to be a simple procedure to be performed by any surgeon on call who was experienced in laparoscopic appendicectomy or similar procedures. However, this might not have been true as reflected by the high number of included cancers and missed overt perforations. Many of the surgeons involved had hardly any experience in laparoscopic lavage for perforated diverticulitis, and the low number of patients per participating hospital did not provide sufficient patients for a learning curve during the trial. Training would have been difficult with these patient numbers, but quality control with video would have been possible.

Finally, it must be pointed out that end-of-life cost calculation is based on assumptions about future events rather than facts, as such data are currently not available. However, this estimation was considered to be of such clinical importance, in addition to the available 12-month data, that it was used rather than waiting for the long-term (retrospective) data from the trial.

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References

1 Peery AF, Dellon ES, Lund J, Crockett SD, McGowan CE, Bulsiewicz WJ *et al*. Burden of gastrointestinal disease in the United States: 2012 update. *Gastroenterology* 2012; **143**: 1179–1187.e1–e3.

2 Delvaux M. Diverticular disease of the colon in Europe: epidemiology, impact on citizen health and prevention. *Aliment Pharmacol Ther* 2003; **18**(Suppl 3): 71–74.

3 Morris CR, Harvey IM, Stebbings WS, Hart AR. Incidence of perforated diverticulitis and risk factors for death in a UK population. *Br J Surg* 2008; **95**: 876–881.

4 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**: 432–434.

5 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.

6 Toorenvliet BR, Swank H, Schoones JW, Hamming JF, Bemelman WA. Laparoscopic peritoneal lavage for perforated colonic diverticulitis: a systematic review. *Colorectal Dis* 2010; **12**: 862–867.

7 Vennix S, Musters GD, Mulder IM, Swank HA, Consten EC, Belgers EH *et al*.; Ladies trial colloborators. Laparoscopic peritoneal lavage or sigmoidectomy for perforated diverticulitis with purulent peritonitis: a multicentre, parallel-group, randomised, open-label trial. *Lancet* 2015; **386**: 1269–1277.

8 Angenete E, Thornell A, Burcharth J, Pommergaard HC, Skullman S, Bisgaard T *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**: 117–122.
9 Schultz JK, Yaqub S, Wallon C, Blecic L, Forsmo HM, Folkesson J *et al*.; SCANDIV Study Group. Laparoscopic lavage *vs* primary resection for acute perforated diverticulitis: the SCANDIV randomized clinical trial. *JAMA* 2015; **314**: 1364–1375.
10 Swank HA, Vermeulen J, Lange JF, Mulder IM, van der Hoeven JA, Stassen LP *et al*.; Dutch Diverticular Disease Collaborative Study Group. 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.
11 Volksgezondheidenzorg.info. https://www.volksgezondheidenzorg.info/onderwerp/levensverwachting/cijfers-context/huidige-situatie#node-resterende-levensverwachting [accessed 2 March 2016].
12 van de Wall BJ, Draaisma WA, Schouten ES, Broeders IA, Consten EC. Conventional and laparoscopic reversal of the Hartmann procedure: a review of literature. *J Gastrointest Surg* 2010; **14**: 743–752.
13 Moreno AM, Wille-Jorgensen P. Long-term outcome in 445 patients after diagnosis of diverticular disease. *Colorectal Dis* 2007; **9**: 464–468.
14 Eglinton T, Nguyen T, Raniga S, Dixon L, Dobbs B, Frizelle FA. Patterns of recurrence in patients with acute diverticulitis. *Br J Surg* 2010; **97**: 952–957.
15 Klaristenfeld DD, McLemore EC, Li BH, Abbass MA, Abbas MA. Significant reduction in the incidence of small bowel obstruction and ventral hernia after laparoscopic compared to open segmental colorectal resection. *Langenbecks Arch Surg* 2015; **400**: 505–512.
16 Hakkaart-van Roijen L. *Short Form – Health and Labour Questionnaire (SF-HLQ)*. Institute for Medical Technology Assessment, Erasmus Medical Centre: Rotterdam, 2007.
17 Hakkaart-van Roijen L, Tan SS, Bouwmans CAM. [*Handleiding voor Kostenonderzoek, Methoden en Standaard Kostprijzen voor Economische Evaluaties in de Gezondheidszorg*.] College voor Zorgverzekeringen: Rotterdam, 2010.
18 Crawshaw BP, Chien HL, Augestad KM, Delaney CP. Effect of laparoscopic surgery on health care utilization and costs in patients who undergo colectomy. *JAMA Surg* 2015; **150**: 410–415.
19 Barber JA, Thompson SG. Analysis of cost data in randomized trials: an application of the non-parametric bootstrap. *Stat Med* 2000; **19**: 3219–3236.
20 Bartels SA, Vlug MS, Hollmann MW, Dijkgraaf MG, Ubbink DT, Cense HA *et al*.; Collaborative LAFA Study Group. Small bowel obstruction, incisional hernia and survival after laparoscopic and open colonic resection (LAFA study). *Br J Surg* 2014; **101**: 1153–1159.
21 Cirocchi R, Farinella E, Trastulli S, Sciannameo F, Audisio RA. Elective sigmoid colectomy for diverticular disease. Laparoscopic *vs* open surgery: a systematic review. *Colorectal Dis* 2012; **14**: 671–683.
22 Arkenbosch J, Miyagaki H, Kumara HM, Yan X, Cekic V, Whelan RL. Efficacy of laparoscopic-assisted approach for reversal of Hartmann's procedure: results from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database. *Surg Endosc* 2015; **29**: 2109–2114.
23 Oberkofler CE, Rickenbacher A, Raptis DA, Lehmann K, Villiger P, Buchli C *et al*. A multicenter randomized clinical trial of primary anastomosis or Hartmann's procedure for perforated left colonic diverticulitis with purulent or fecal peritonitis. *Ann Surg* 2012; **256**: 819–826.

Supporting information

Additional supporting information may be found in the online version of this article:

Appendix S1 Results of cost-effectiveness and cost-utility analyses (Word document)

Table S1 Dutch unit costs for all resources used (Word document)

Table S2 Estimated medical costs for follow-up, from 12 months to estimated end-of-life per patient (Word document)

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