National Institute of Health and Care Excellence

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Diverticular disease: diagnosis and management

Cost-effectiveness analysis: laparoscopic lavage versus resection for perforated diverticulitis

NICE guideline NG147

Economic analysis report

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Final

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1.1 Introduction

Laparoscopic lavage for the treatment of perforated diverticulitis is a faster lower cost procedure than resection and it leaves fewer people with a long-term stoma. There is also a trend to reduced mortality but there appear to be more complications and morbidity. The cost of procedures and long-term care are high and therefore it is important to weigh up the costs and benefits systematically.

Two published economic evaluations[1,2] have evaluated this comparison but they did not incorporate the results of the SCANDIV trial[3], which had somewhat different findings to the other two included trials.

The committee considered that the use of lavage is currently not common in the UK for treating diverticular perforation and that implementing this recommendation may therefore require a change from current practice by the majority of providers. For these reasons, this question was prioritised for original modelling.

1.2 Methods

1.2.1 Model overview

A cost-utility analysis was undertaken comparing laparoscopic lavage with resection.

1.2.1.1 Population

The population in the analysis was adults aged 18 and over with perforated acute diverticulitis and purulent peritonitis.

1.2.1.2 Comparators

The comparators selected for the model were:

- Laparoscopic lavage
- Resection, by either:
    - Hartmann’s procedure, or
    - Primary anastomosis, with or without diverting ileostomy

1.2.1.3 Perspective, time horizon, discount rates used

Costs were from a UK NHS and personal social services perspective.

The time horizon of the analysis is 10 years rather than lifetime, due to the absence of data describing long-term mortality following Hartmann’s procedure and primary anastomosis. However, it was clear that extending the time horizon would only lead to the optimal strategy being even more cost effective, since there were fewer people receiving stoma care at 10 years and more people alive.

The analysis follows the standard assumptions of the NICE reference case including discounting at 3.5% for costs and health effects, and incremental analysis is conducted. [22]

1.2.2 Approach to modelling

We estimated costs and QALYs using a decision tree for the first 12 months and then a Markov model for the next 10 years.

We checked the key outcomes at 12 months and compared them with the meta-analyses in the guideline review (See Chapter O). We then adjusted the base case model so that it reflected these results.

Generally, where there were simplifications made, these were deliberately made so as to favour resection rather than lavage. For example, we did not include recurrence of diverticulitis in patients who are receiving stoma care.

1.2.2.1 Decision tree

A decision tree was used to estimate the costs and QALYs associated with either laparoscopic lavage or resection up to one year after the initial intervention. Figure 1 shows the structure of the decision tree. The probabilities used in the decision tree were calculated from the one-year results of the three RCTs identified in the clinical review for this question.

The decision tree was designed to capture:

- The difference in the number of patients living with a stoma
- The difference in the number of reoperations, including
    - Colostomy reversal
    - Ileostomy reversal
    - Subsequent resectional surgery in the laparoscopic lavage arm
- The difference in mortality

The only re-operations in the resection arm were stoma and ileostomy reversal procedures. For simplicity emergency resections in that arm, were not included. However, the number is relatively small and omitting them allows us to be more cautious about laparoscopic lavage.

At the end of the decision tree (at 12 months), patients are in one of four states: Post-lavage, Post-anastomosis, Stoma and, Dead. There will be a proportion of patients from the Laparoscopic lavage arm in each of those states, since patients can have resection subsequent to their lavage. For the Resection arm, there will be no one in the Post-lavage state, since Lavage is restricted to the Laparoscopic lavage arm. It is assumed that people only have one laparoscopic lavage in the model.

Figure 1: Decision tree structure

Ileo=ileostomy

1.2.2.2 Markov model

In a Markov model (or state transition model) a set of mutually exclusive health states are defined that describe what can happen to the population of interest over time. Possible transitions are defined between each of the health states. The probability of each transition occurring within a defined period of time (a cycle) is assigned. Some of these probabilities, such as mortality, are time-dependent in the model – they change as the population recovers but also grows older.

A Markov model with 9 health states was constructed. Figure 3 shows the model structure and possible transitions between health states. A cycle length of 6 months was used in the Markov model. There were 36 cycles covering years 2-10 of the overall model.

The model contains four ‘chronic states’:

- Post-lavage,
- Post-anastomosis,
- Stoma, and
- Dead.

People can’t move out of the Dead state. People each of the other three chronic states, remain in that state until they have a procedure or die.

Five surgical procedures are represented by the following ‘acute states’:

- Hartmann’s procedure
- Primary anastomosis (with diverting ileostomy)
- Primary anastomosis (without diverting ileostomy)
- Colostomy reversal
- Ileostomy reversal.

People move out of these states in the following cycle.

The Markov model captures the impact of:

- recurrence and resection in the post-lavage arm,
- colostomy reversal, and
- worse survival and quality of life for those in the stoma state (in sensitivity analyses).

For those people who have a Hartmann’s procedure, a proportion will have a reversal procedure in the next cycle. That procedure is not 100% successful. Those people for whom it is successful will transition to the post-anastomosis state. The others will transition to the stoma state. For those in the stoma state there is a constant rate of reversal attempt for the remaining cycles of the model.

It is assumed that all patients who survive a primary anastomosis with diverting ileostomy will have a reversal. That reversal will take place in the following 6-month cycle and for those that survive the reversal procedure, it will be successful and they move to the post-anastomosis state.

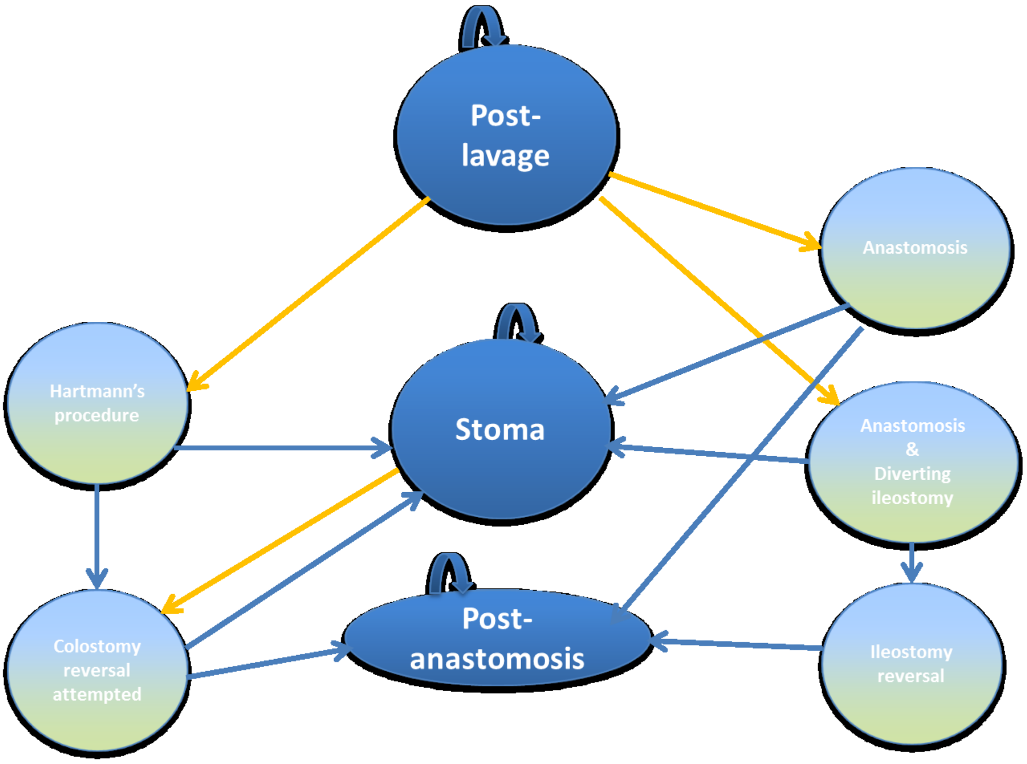
For patients that have a primary anastomosis without diverting ileostomy there is a probability that this procedure will fail due to anastomotic leak. These patients will move to the stoma state.

To simplify the model, we assume there are no additional resections for people in the post-anastomosis state and only colostomy reversals in the stoma state. This assumption should favour resection over lavage. People in the model cannot transition to the post-laparoscopic lavage state after resection, nor receive a second laparoscopic lavage. This was thought to represent clinical practice.

The model is run for repeated cycles, and the time spent in the different health states is calculated. By attributing costs and quality of life weights to each of the health states, total costs and QALYs can be calculated for the population.

The people entering each of the states at year 1 are distributed differently for the different comparators (lavage and resection). This is determined by the results of the decision tree. Therefore, the comparators will have different total costs and QALYs.

Figure 2: Markov model structure



Also, every cycle there is a probability of moving to a 'Dead' state from each of the other states.

1.2.2.3 Uncertainty

The model was built probabilistically to take account of the uncertainty around input parameter point estimates. A probability distribution was defined for each model input parameter. When the model was run, a value for each input was randomly selected simultaneously from its respective probability distribution; mean costs and mean QALYs were calculated using these values. The model was run repeatedly – 10,000 times for the base case analysis and 5,000 times for each sensitivity analysis – and results were summarised. This is known as Monte Carlo simulation.

We checked for convergence by plotting on a graph the cumulative incremental costs and incremental QALYs for Lavage versus Resection after each iteration. The base case results had clearly converged by the 5000th iteration

The way in which distributions are defined reflects the nature of the data, so, for example, probabilities were given a beta distribution, which is bounded by 0 and 1, reflecting that a probability cannot be outside this range. Probability distributions in the analysis were parameterised using error estimates from data sources.

In addition, various sensitivity analyses were undertaken to test the robustness of model assumptions. In each of these, one or more inputs were changed and the analysis rerun to see if the optimal strategy changes.

1.2.3 Model inputs

1.2.3.1 Decision tree probabilities

In the base case, probabilities used in the decision tree (Table 1 and Table 2) were calculated, where possible, from the one-year results of all three RCTs identified in the systematic review combined.

For outcomes with a total sample size of 30 or larger, we conducted a meta-analysis of the probabilities.

For some probabilities, there were less than 30 in the pooled sample. In these circumstances, we calculated the probability by simply dividing the sum of the events by the sum of the sample sizes.

For some probabilities, the total sample size was very small indeed, for example, the outcomes after primary anastomoses in the lavage arm. In two sensitivity analyses, we attempted to overcome this by either pooling the probabilities across both arms or by using observational data – see Table 2. However, for the base case, we stuck to the crude figures from the trials, so that the key outcomes (mortality, stoma and reoperations) were consistent with the trial reports and the guideline review. The one exception was that we chose to use only the LADIES and SCANDIV trials to estimate the ratio of Hartmann's procedure to primary anastomosis in the resection arm. The DILALA trial had only Hartmann's procedure.

Table 1: Relative frequency of each type of resection in the base case analysis

Input	Lavage arm	Source
Resection arm (index procedure: all patients)		
Resection by Hartmann's procedure	0.651 =71/109	LADIES, SCANDIV[3, 4]
Resection by anastomosis	0.349 =38/109	LADIES, SCANDIV[3, 4]
Resection with diverting ileostomy / All resection by anastomosis	0.700 =14/20	LADIES[4]
Laparoscopic lavage arm (only those patients that go on to have resection)		
Resection by Hartmann's procedure	0.676 (25/37)	LADIES, SCANDIV[3, 4]
Resection by anastomosis	0.243 =12/37	LADIES, SCANDIV[3, 4]
Resection with diverting ileostomy / All resection by anastomosis	0.25 =3/12	LADIES, SCANDIV[3, 4]

Meta-analysis methods

Where formal meta-analysis was conducted, this was carried out in WinBUGS version 1.4.3 using the method proposed by the NICE Decision Support Unit.[5] This is a Bayesian form of logistic regression analysis using non-informative priors:

- Log odds of an event m~N(0, 100^2).
- Between-study heterogeneity sd.m ~ uniform(0,5).

We conducted both a fixed-effects and random-effects analysis. However, for no outcome was the Deviation Information Criterion (DIC) more than 5 points lower for the random effects analysis, suggesting that the random effects analysis was not fitting the data any better than the fixed-effects analysis. Therefore, we used the results of the fixed effects analysis in the model. This is likely to reflect the difficulty in estimating the between study variance from only three studies rather than a lack of heterogeneity per se. We used 60,000 burn-in iterations and 60,000 sample iterations from each of 3 chains, but the estimates had stabilised by the 1000th iteration. The code can be found at the end of this appendix – see 2.1

Table 2: Event probabilities used in the decision tree

	Base case		**Sensitivity analysis 1**	**Sensitivity analysis 4**
Input	**Lavage arm**	**Resection arm**	**Pooled across arms**	**Using estimates from Markov model**
Outcomes of laparoscopic lavage				
Mortality after laparoscopic lavage, without other interventions	0.057* =9/163 [3, 4, 6]	N/A	As base case	As base case
Resection, following laparoscopic lavage	0.270 =44/163 [3, 4, 6]	N/A	As base case	As base case
Outcomes of Hartmann's Procedure				
Mortality, without reversal	0.281 =9/32 [3, 4, 6]	0.141 =10/71 [3, 4]	0.184 =19/103	0.152(a)
Stoma reversal operation	0.188 =6/32 [3, 4, 6]	0.481 =51/106 [3, 4, 6]	0.413 =57/138	As base case (not pooled)
Failed reversal procedure (new stoma)	0 =0/5[3, 4]	0.033 =1/30[3, 4]	0.029 =1/35	0.105(b)
Mortality following reversal, or reversal-related	0 =0/5[3, 4]	0.033 =1/30[3, 4]	0.029 =1/35	0.017(a)
Outcomes of anastomosis without diverting ileostomy				
Mortality	0.125 =2/10[3, 4]	0.042 =1/24[3, 4]	0.089 =3/34	0.032(a)
Anastomosis failure	0 =0/10[3, 4]	0 =0/24[3, 4]	0 =0/34	0.079(c)
Outcomes of anastomosis with diverting ileostomy				
Mortality following anastomosis before reversal	0 =0/3[3, 4]	0.143 =2/14[4]	0.118 =2/17	0.108(a)
Reversal operation for diverting ileostomy failure	0 =0/1[4]	0 =0/12[4]	0 =0/13	0.079(c)
Mortality following reversal of diverting ileostomy or reversal-related	0 =0/1[4]	0 0/12[4]	0 =0/13	0.010(a)

** The raw probability was 0.055 but this was adjusted so that the absolute mortality effect in the model was no greater than that found in the guideline's systematic review – see 1.2.5.*

(a) Hospital Episode Statistics linked to ONS - seeTable 3

(b) See Table 5

(c) The probability of anastomotic leak, 5.97.8% (31/52923/293), was calculated by pooling from the primary anastomosis arms of three RCTs and 9 observational studies in our review of primary versus secondary anastomosis (See Chapter M).

Surgery type

In the resection arm, the probability of undergoing either Hartmann's procedure or anastomosis (with or without diverting ileostomy) was obtained from the SCANDIV and LADIES trials. In the LADIES RCT, people with perforated diverticulitis allocated to the resection arm were randomised between Hartmann's procedure and anastomosis. The DILALA RCT did not include anastomosis as an intervention.

The SCANDIV RCT did not report the number of people in the resection arm undergoing anastomosis as an index procedure who were diverted with an ileostomy. This was available in the LADIES RCT.

In DILALA, anastomosis with or without diverting ileostomy was not reported as a re-intervention and so all resections were assumed to be Hartmann's procedures.

In sensitivity analyses, we varied the proportion of patients in the resection arm having Hartmann's procedure (rather than primary anastomosis) between 0% and 100%.

Outcome of surgery

In the laparoscopic lavage arm, successful laparoscopic lavage was defined as 'alive, without resection as a re-intervention at 1 year'. This was extracted from each of the three RCTs. The proportion of people undergoing resection within 1 year in the laparoscopic lavage arm was also reported in each of the RCTs.

Where the outcomes following resection were not explicitly reported, they were inferred from the other outcomes: 'alive with stoma', 'alive stoma free', 'never had a stoma', 'stoma reversal' and 'mortality'. For example, in the laparoscopic lavage arm of DILALA, there were seven Hartmann's procedures, one reversal operation and three people alive with a stoma at 1 year. Three people with stomas were therefore assumed to have died, without undergoing reversal. As six people died in the laparoscopic lavage arm of DILALA, three people were therefore assumed to have died following laparoscopic lavage with no other intervention.

As DILALA did not include anastomosis as an intervention in the resection arm and did not report any instances of anastomosis as a re-intervention in the laparoscopic lavage arm at one year, outcomes following anastomosis with and without diverting ileostomy are from the LADIES and SCANDIV RCTs.

As there were low numbers of events for outcomes of Hartmann's procedure and anastomosis with and without diverting ileostomy *after laparoscopic lavage*, in a sensitivity analysis, the numbers from both the laparoscopic lavage and resection arms of the RCTs were pooled. Therefore, the outcomes (e.g. colostomy reversal or mortality after Hartmann's procedure) are the same in the resection and laparoscopic lavage arms.

In another sensitivity analysis, data from national statistics were used for the mortality of each procedure – see Table 3 .

Since the SCANDIV trial did not find any trend towards benefit in terms of mortality or reoperation rates, another sensitivity analysis was conducted using only data from that trial. Other sensitivity analyses included increasing the colostomy reversal rate to 75% and increasing the probability of resection after laparoscopic surgery to 50%, both arbitrarily high estimates.

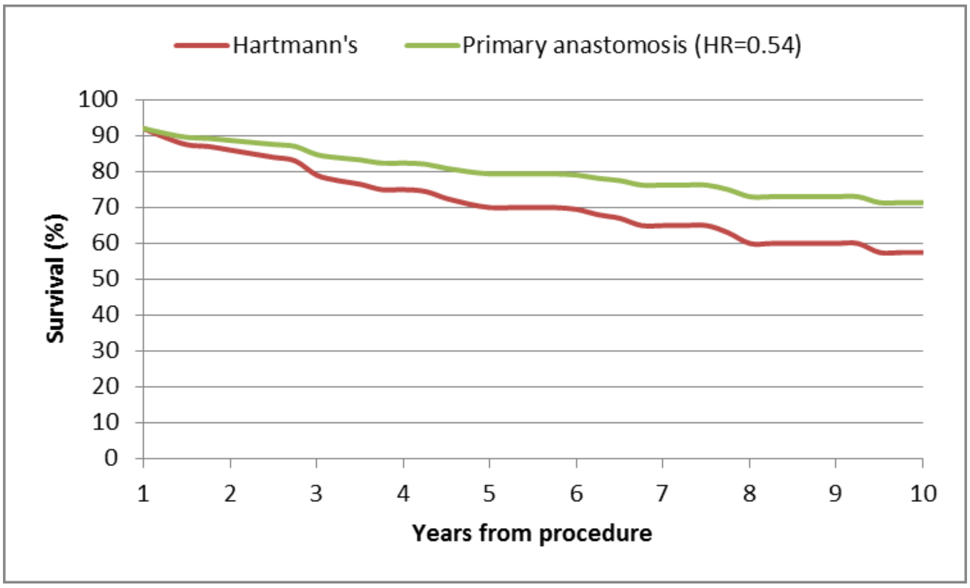
1.2.3.2 Markov model transition probabilities

Mortality in the chronic states

A time-dependent mortality probability was applied to the people in the 'chronic' health states of the model: stoma, post-anastomosis and post- lavage. These probabilities are based on a published survival analysis in a cohort of 340 people undergoing emergency surgery for perforated acute diverticulitis in the Netherlands between January 1990 and December 2005[7].

For the stoma state, we used the Kaplan-Meier curve to derive time-dependent mortality probabilities. A hazard ratio was calculated for primary anastomosis versus Hartmann's procedure controlling for age, ASA (American Society of Anesthesiologists) class, Hinchey score and MPI (Mannheim Peritonitis Index): 0.54 (95% CI 0.3 – 1.04; p=0.07). However, this hazard ratio was applied only in a sensitivity analysis - Figure 3. In the base case, we applied the same survival curve to all three chronic states.

Figure 3: Survival after Hartmann's and primary anastomosis, beyond 12 months.



Mortality in the acute states

For the surgical procedures we extracted national statistics for the 3 month mortality – The Hospital Episode Statistics (HES) linked to Office for National Statistics (ONS) data [8] – see Table 3.

Table 3: Mortality in the acute states

	Hospital episode statistics linked to ONS			RCTs	Model	
	Deaths in 90 days	Sample size	90 day prob-ability	12 month prob-ability	6 month probability	OPCS4 code used
Hartmann's procedure	65	545	11.9%	18.4%	15.2%	H105 Sigmoid colectomy and exteriorisation of bowel NEC
Primary anastomosis	17	771	2.2%	8.8%	5.5%	H103 Sigmoid colectomy and anastomosis NEC
Anastomosis with diverting ileostomy	24	244	9.8%	11.8%	10.8%	H104 Sigmoid colectomy and ileostomy HFQ
Colostomy reversal	11	2042	0.5%	2.9%	1.7%	H154 Closure of colostomy
Ileostomy reversal	50	5170	1.0%	0.0%	1.0%	G743 Closure of ileostomy

These were 3-month probabilities and those from the trials used in the decision tree were 12-month probabilities. For the 6-month transition probabilities in the Markov model, we used the mid-point between these two estimates. The exception was the mortality associated with ileostomy reversal; we used the HES-ONS estimate, since there appeared to be no deaths in the trials. In a sensitivity analyses we used the higher probabilities.

Recurrence and resection in the post-lavage state

A pragmatic search of the literature was conducted for epidemiological data relating to patients experiencing complicated diverticulitis. For the recurrence and resection rates, we used a study that followed up 3222 people diagnosed with diverticulitis between 1980 and 2007 in Minnesota [9]. This study was chosen because it:

- compared surgically treated with conservatively treated patients,
- compared complicated and uncomplicated index episodes,
- sub grouped patients by first/second episode of acute diverticulitis, and
- had a substantial sample size and long follow-up.

The rates (Table 4) were for people who were treated conservatively at diagnosis and were stratified according to whether it was their first or second acute episode of diverticulitis.

We used the former in the base case and the latter in a sensitivity analysis. The raw data was time to first recurrence but we adjusted these rates to account for multiple occurrences, as reported by the trials.

The type of resection was assumed to follow the same pattern as observed in the three randomised trials: 67.6% Hartmann’s procedure, 24.3% anastomosis without diverting ileostomy and 8.1% anastomosis with diverting ileostomy.

Table 4: Recurrence and resection rate after laparoscopic lavage

	10 year probability	Annual rate (unadjusted)	Annual rate (adjusted)	6 month probability
Index case is first episode of diverticulitis				
Recurrence rate	22%	2.50%	3.76%	1.86%
Surgery rate			1.08%(a)	0.54%
Index case is second episode of diverticulitis				
Recurrence rate	50%	6.93%	10.48%	5.11%
Surgery rate			3.02%(a)	1.50%

(a)The ratio of recurrences requiring surgery over all episodes of recurrence was 454/1576=29%.

Stoma reversal

Since in the trials, the rate of colostomy reversal was much higher in the first year after colostomy, we employed a colostomy reversal rate of 41% in the first cycle after the Hartmann's procedure. This was the proportion of colostomies reversed across both arms of the three randomised controlled trials.

Beyond that, the rate of stoma reversal assumed was the average of the probabilities used in the LADIES and DILALA economic analyses beyond 12 months - Table 5. The LADIES economic analysis assumed that 30% of stomas would be reversed over a lifetime time horizon (mean 21 patient-years), of which 93% were successfully reversed. Meanwhile the DILALA economic study assumed that 25% would be reversed (mean 20 years), with an 86% success rate. We used the average of these probabilities but since it is believed that the rate of reversal diminishes over time, we assumed that all of these reversals would occur within our 10-year time horizon.

Table 5: Long-term colostomy reversal rate

Source	Lifetime probability	Annual rate*	6 month cycle transition probability	Success rate
Vennix 2017[2]	30%	3.6%	1.8%	93%
Gehrman 2016[1]	25%	2.9%	1.4%	86%
Median		3.2%	1.6%	90%

**Assuming events occur over 10 years.*

Anastomotic leak with primary anastomosis

The probability of anastomotic leak, 7.8% (23/293), was calculated by pooling from the primary anastomosis arms of three RCTs and 9 observational studies in our review of primary versus secondary anastomosis (See Chapter M).

1.2.3.3 Utilities

A systematic search of the literature was conducted to find utilities. A single study was found that reported EQ-5D after perforated diverticulitis[10]. The long-term quality of life following Hartmann's procedure and primary anastomosis was reported in an observational study of people with surgically managed perforated diverticulitis (Table 6). The study used the Dutch tariff of the EQ-5D. No long-term quality of life data were identified for people with perforated diverticulitis managed using laparoscopic lavage.

Table 6: EQ-5D data after surgically managed perforated diverticulitis

	Hartmann's procedure	Primary anastomosis	General population (age-sex matched)
Sample size	76	53	76
Median age in years	62	59	62
Sex - M/F	52%/48%	40%/60%	52%/48%
Median follow up in months	72	69	NR
Mean EQ-5D Index (range)	0.67 (-0.18-1.0)	0.77 (0.67-0.93)	0.77 (0.67-0.92)

In the base case, we used the lower score (0.67) for people in acute states and the higher score (0.77) for people in the chronic states, regardless of what procedure they had. The quality of life evidence collected in the three trials generally did not show any difference in quality of life between lavage and resection.

In a sensitivity analysis, we used the lower estimate for people in the chronic stoma state.

In a second sensitivity analysis, we applied a utility decrement to the post-lavage state. The review had found a greater proportion of people with morbidity or complications in the lavage arm (49% vs 38%). In this analysis, we applied the higher estimate of utility (0.77) to people who did not have morbidity and a decrement of 0.2 (that is 0.57) to those that did. This yielded a utility of 0.70 in the post-resection states and 0.67 in the post-lavage state.

Applying the utility in the decision tree

To calculate the QALYs in the 12 months of the decision tree, it was assumed that those people that died, did so at 6 months. For these people, their QALYs were equal to the lower utility of 0.67 in Table 6 divided by two.

All other patients, were also attributed the lower utility for the first 6 months of the year.

The utility applied from 6 months to 12 months in the base case analysis was the higher estimate of 0.77. In the sensitivity analyses, the utility was assigned according to their state at the end of the year, as described above.

Applying the utility in the Markov model

As each cycle is 6 months, the utilities were multiplied by 0.5 years, to give the QALYs for that cycle.

In the base case analysis, the higher utility of 0.77 was used for all three chronic states. In the sensitivity analyses, this utility varied by state, as described above.

The lower utility of 0.67 was used for the acute states.

In addition, those patients (in the post-lavage state) that incurred a recurrence of diverticulitis had a 'disutility' subtracted from their QALYs equivalent to one month's utility (0.77x1/12). This was believed to be a conservatively high estimate of the QALY loss.

1.2.3.4 Resource use and costs

The unit costs used in the model for all the procedures are listed in Table 7. They were sourced from the NHS reference costs 2016-17[11]. In addition to the cost of the procedure, surgical outpatient follow-up costs (£112) were included as follows:

- 2 for Hartmann's procedure,

- 2 for primary anastomosis and diverting ileostomy,
- 1 for primary anastomosis without diverting ileostomy,
- 1 for laparoscopic lavage
- 1 for ileostomy reversal, and
- 1 for colostomy reversal.

In addition, two face-to-face and 2 telephone consultations with a stoma nurse for patients having Hartmann's procedure or diverting ileostomy.

Table 7: Procedure costs used in the model

Procedure	OPCS 4 procedure label	Healthcare Resource Group (HRG) code	Unit Cost	Average Length of Stay
Laparoscopic lavage	Introduction of substance into peritoneal cavity	FF52 Intermediate Therapeutic General Abdominal Procedures (Non-elective)	£3,891	5.2 days
Anastomosis without diverting ileostomy	Sigmoid colectomy and anastomosis	FF33 Distal Colon Procedures (Non-elective)	£7,091	9.0 days
Anastomosis with diverting ileostomy	Sigmoid colectomy and ileostomy HFQ	FF31 Complex Large Intestine Procedures (Non-elective)	£8,228	11.0 days
Hartmann's procedure	Sigmoid colectomy and exteriorisation of bowel NEC	FF31 Complex Large Intestine Procedures (Non-elective)	£8,228	11.0 days
Stoma reversal	Sigmoid colectomy and anastomosis	FF33 Distal Colon Procedures (Elective)	£6,487	5.2 days
Ileostomy reversal	Closure of ileostomy	FF22 Major Small Intestine Procedures (Elective)	£5,151	5.6 days
Colonoscopy		FE32Z Diagnostic colonoscopy, 19 years and over, colorectal surgery outpatient)	£469	n/a
Outpatient follow-up		WF01A - Non-Admitted Face-to-Face Attendance, Follow-up, Colorectal surgery	£112	n/a

Abbreviations: HFQ=However further qualified; n/a=not applicable; NEC=Not elsewhere classified; OPCS=Office of Population, Census and Survey

Table 8: Three-month costs of continuing stoma care

Parameter description	Unit cost	Resource use	Cost per 6 months
Stoma care			
Stoma care services, face-to-face (N24AF)	£51.15	1 per year, once established	£12.79
Stoma care services, non-face-to-face (N24AN)	£22.73	2 per year	£11.36
Colostomy pouch	£2.96	3 times daily	£810.86
Adhesive remover	£7.00	1 per week	£91.00
TOTAL			**£926.01**
Ileostomy care			
Stoma care services, face-to-face	£51.15	1 per year, once	£12.79

Parameter description	Unit cost	Resource use	Cost per 6 months
(N24AF)		established	
Stoma care services, non-face-to-face (N24AN)	£22.73	2 per year	£11.36
Ileostomy pouch	£3.32	5 per week	£215.80
Adhesive remover	£7.00	1 per month	£21.00
TOTAL			**£260.95**

The cost of readmission for recurrence (post-lavage state only) without a surgical procedure was £2108 based on our other model evaluating the use of CT for suspected diverticulitis. To be conservative we used the higher cost based on a stay of 5 days stay, intravenous antibiotics and CT scan. At a rate of 3.76% per year, this amounted to only £39 per person per cycle.

A one-off cost of a colonoscopy was included after laparoscopic lavage.

Applying the costs in the decision tree

For costing stoma care, the following assumptions were made:

- In the lavage arm if resection takes place in the first year then it is assumed to take place at 3 months
- If stoma reversal was not attempted, or if reversal failed, then the time with stoma in the decision tree was
  - 12 months in the resection arm.
  - 9 months in the lavage arm.
- Death was assumed to occur at 6 months.
- Stoma reversal was assumed to occur at 6 months (12 months in a sensitivity analysis)
- Ileostomy reversal was assumed to occur at 3 months (6 months in a sensitivity analysis)
- If ileostomy reversal was unsuccessful, the cost of the remaining 9 months of stoma care was applied.

Applying the costs in the Markov model

The combined costs of surgery, outpatient consultations and stoma care for each cycle are shown by state in Table 9. To be consistent with the decision tree, where stoma reversal occurs in the same year as the Hartmann’s procedure, it is assumed that it takes place at 6 months (12 months in a sensitivity analysis).

Table 9: Costs used in the Markov model

Health state	Cost (£)	Content
Post-lavage	39	Readmission for recurrence
Stoma	1,852	Stoma care
Post-anastomosis	-	
Hartmann’s	10,452	Procedure, follow-up and stoma care
Anastomosis	7,203	Procedure and follow-up

Health state	Cost (£)	Content
Anastomosis with diverting ileostomy	9,121	Procedure, follow-up and stoma care
Colostomy reversal	6,794	Procedure and follow up
Ileostomy reversal	5,263	Procedure and follow up

The following unit costs were varied in separate sensitivity analyses: Laparoscopic lavage (50% higher); Stoma care (50% lower); Stoma reversal (50% lower); readmission for recurrence without procedure (50%) higher.

1.2.4 Computations

The model was constructed in Microsoft Excel 2010 and was evaluated by cohort simulation.

1.2.4.1 Rates and probabilities

Mortality rates were converted into transition probabilities for the cycle length (6 months) before inputting into the Markov model. The probability of the event over the time horizon specified by the literature was converted into a rate, before being converted into a probability appropriate for the cycle length. The above conversions were done using the following formulae:

$Selected\ rate\ (r) = \frac{-\ln(1-P)}{t}$	Where *P*=probability of event over time *t* *t*=time over which probability occurs (in years)
$Transition\ Probability\ (P) = 1 - e^{-rt}$	Where *r*=selected rate *t*=cycle length (=0.5 years)

1.2.4.2 Discounting

QALYs and costs were calculated in each cycle. They were then discounted to reflect time preference (both using a discount rate of 3.5% per year) using the following formula:

Discounting formula:

$\text{Discounted total} = \frac{\text{Total}}{(1+r)^n}$	Where: *r*=discount rate per year *n*=time (years)

1.2.4.3 Parameterising distributions used in the probabilistic analyses

Probability distributions in the analysis were parameterised using error estimates from data sources.

Table 10: Description of the type and properties of distributions used in the probabilistic sensitivity analysis

Parameter	Type of distribution	Properties of distribution
Probability pooled from multiple studies	Beta	Bounded between 0 and 1. Derived from mean and standard deviation (SD) of the posterior distribution, using the method of moments. Alpha and Beta values were calculated as follows:

Parameter	**Type of distribution**	**Properties of distribution**
		Alpha = $\text{mean}^2 \times [(1-\text{mean})/SD^2]-\text{mean}$ Beta = $\text{Alpha} \times [(1-\text{mean})/\text{mean}]$
Probability where the sample size is known	Beta	Bounded between 0 and 1. Alpha and Beta values were calculated as follows: Alpha = number of patients with the event Beta = Sample size minus alpha
Probability where the sample size is *not* known (e.g. colostomy reversal and colostomy reversal success)	Beta	Bounded between 0 and 1. Derived assuming that the standard error (SE) is 20% of the mean (point estimate), using the method of moments. Alpha and Beta values were calculated as follows: Alpha = $\text{mean}^2 \times [(1-\text{mean})/SE^2]-\text{mean}$ Beta = $\text{Alpha} \times [(1-\text{mean})/\text{mean}]$
Multinomial probability (e.g. outcome of Hartmann's procedure in decision tree)	Dirichlet	Represents a series of conditional distributions, bounded on 0–1 interval. Parameters are the number of patients in each category.
Utility	Beta	Bounded between 0 and 1. Since the standard error was non reported for the utilities used we used the method of moments as follows Alpha and Beta values were calculated as follows: Alpha = sample size x mean Beta = Sample size x (1-mean)
Recurrence rate	Gamma	Bounded at 0, positively skewed. Derived from mean and its standard error. Alpha and Beta values were calculated as follows: Alpha = $(\text{mean}/SE)^2$ Beta = SE^2/Mean
NHS Reference Costs	Gamma	Bounded at 0, positively skewed. Derived from mean and its standard error. Alpha and Beta values were calculated as follows: Alpha = $(\text{mean}/SE)^2$ Beta = SE^2/Mean Where SE was estimated from the upper quartile (UQ) and lower quartile (LQ) as follows: $SE=(UQ-LQ)/2Z_{0.75}$

The following variables were left deterministic (that is, they were not varied in the probabilistic analysis):

- timing of events in first year (resection, stoma reversal and death),
- timing of stoma reversal within the Markov cycle,
- the number of outpatient appointments,
- the number and price of consumables
- probabilities that were zero or one.

A full list of the probabilistic model parameters can be found at the end of this report – see section 3.

1.2.5 Model validation

The model was developed in consultation with the committee; model structure, inputs and results were presented to and discussed with the committee for clinical validation and interpretation.

The model was systematically checked by the health economist undertaking the analysis; this included inputting null and extreme values and checking that results were plausible given inputs. The model was peer reviewed by a second experienced health economist from the NGC; this included systematic checking of the model calculations.

We checked that the base case analysis reflected closely, the main findings of the guideline's review - Table 11-. As a result, the following recalibrations were conducted:

- The mortality for patients who die after lavage (without having resection) was increased from 5.5% to 5.7%.
- The cost of lavage was adjusted to counteract the slight over-estimate of reoperations averted by adding a cost of £439 per patient to the year 1 cost in the lavage arm (£7,203 x 0.06 operations). Here, £7,203 was the cost of a primary anastomosis and 0.06 was the difference in mean difference between the model and the review (0.17-0.11) – see Table 11.

Table 11: Comparison of model outcomes and guideline review Lavage versus resection

	Relative effect		Absolute effect		
	Review	Model before calibration	Review	Model before calibration	Model after calibration
Mortality at 12 months	0.84	0.87	-0.019	-0.021	-0.019
Stoma at 12 months	0.32	0.36	-0.21	-0.18	-0.18
All reoperations at 12 months	0.82	0.66	-0.11	-0.17	-0.11
Recurrence after lavage per year (Markov model)			+0.019	+0.019	+0.019

1.2.6 Estimation of cost effectiveness

The widely used cost-effectiveness metric is the incremental cost-effectiveness ratio (ICER). This is calculated by dividing the difference in costs associated with 2 alternatives by the difference in QALYs. The decision rule then applied is that, if the ICER falls below a given cost per QALY threshold then the result is considered cost effective. If both costs are lower and QALYs are higher the option is said to dominate and an ICER is not calculated.

$$ICER = \frac{Costs(B) - Costs(A)}{QALYs(B) - QALYs(A)}$$

Where: Costs(A) = total costs for option A; QALYs(A) = total QALYs for option A

Cost effective if:

- ICER < Threshold

1.2.7 Interpreting Results

NICE's report 'Social value judgements: principles for the development of NICE guidance'[12] sets out the principles that committees should consider when judging whether an intervention offers good value for money. In general, an intervention was considered cost effective if either of the following criteria applied (given that the estimate was considered plausible):

- The intervention dominated other relevant strategies (that is, it was both less costly in terms of resource use and more clinically effective compared with all the other relevant alternative strategies), or
- The intervention costs less than £20,000 per quality-adjusted life-year (QALY) gained compared with the next best strategy.

1.3 Results

1.3.1 Base case

All results presented are based are average results from the probabilistic analyses. All future costs and outcomes have been discounted (unless stated otherwise).

The main model health outcomes can be seen in Table 12 and Table 13. The laparoscopic lavage arm had fewer deaths in the first year and longer life expectancy. Time with stoma was reduced.

Table 12: Base case analysis - Health outcomes - at one year

	Deaths	Stoma	Mean life years	Mean QALYs
Laparoscopic lavage	0.122	0.097	0.939	0.673
Resection	0.141	0.272	0.929	0.665
Lavage vs Resection	-0.019	-0.175	0.010	0.007

Table 13: Base case analysis - Health outcomes - all years

	Mean Stoma-years (undiscounted)	Mean Life years (undiscounted)	Mean QALYs (discounted)
Laparoscopic lavage	0.75	6.92	4.54
Resection	2.10	6.80	4.50
Lavage vs Resection	-1.35	0.12	0.04

The cost savings seen at 1 year due to lower cost procedures and less stoma formation were enhanced over the rest of the time horizon by further stoma cost savings (Table 14). The recurrence rate after lavage was quite small and hence the cost of resection and readmission in that arm after year 1 was small. Therefore, beyond year 1, the additional cost of stoma care in the resection arm far outweighed the additional surgery cost.

Table 14: Base case results – Mean costs (£)

	Year 1 Surgery	Year 1 Stoma care	Years 2-10 Surgery	Years 2-10 Stoma care	Non-surgical admission	All costs
Laparoscopic lavage	7,370	387	592	2,034	292	10,676
Resection	11,579	1,766	309	5,185	0	18,839
Lavage vs Resection	-4,209	-1,379	283	-3,151	292	-8,162

As can be seen in Table 15, laparoscopic lavage was both cost saving and had QALY gains compared with resection. These gains were even larger after 10 years than at one year.

Figure 4 shows incremental cost and incremental QALYs plotted against each other – the ‘cost effectiveness plane’. Each of the 10,000 estimates from the probabilistic vase case are plotted. The graph emphasises that under the base case assumptions, it is highly likely that laparoscopic lavage is less costly than resection but highly uncertain whether it has higher QALYs.

Table 15: Base case results - cost effectiveness

	Mean Cost (discounted)	Mean QALYs (discounted)	Cost effectiveness
Year 1			
Laparoscopic lavage	7,757	0.673	
Resection	13,345	0.665	
Lavage vs Resection	- 5,587	0.007	Lavage dominates Resection
All years (1-10)			
Laparoscopic lavage	10,676	4.537	
Resection	18,839	4.498	
Lavage vs Resection	- 8,162	0.039	Lavage dominates Resection

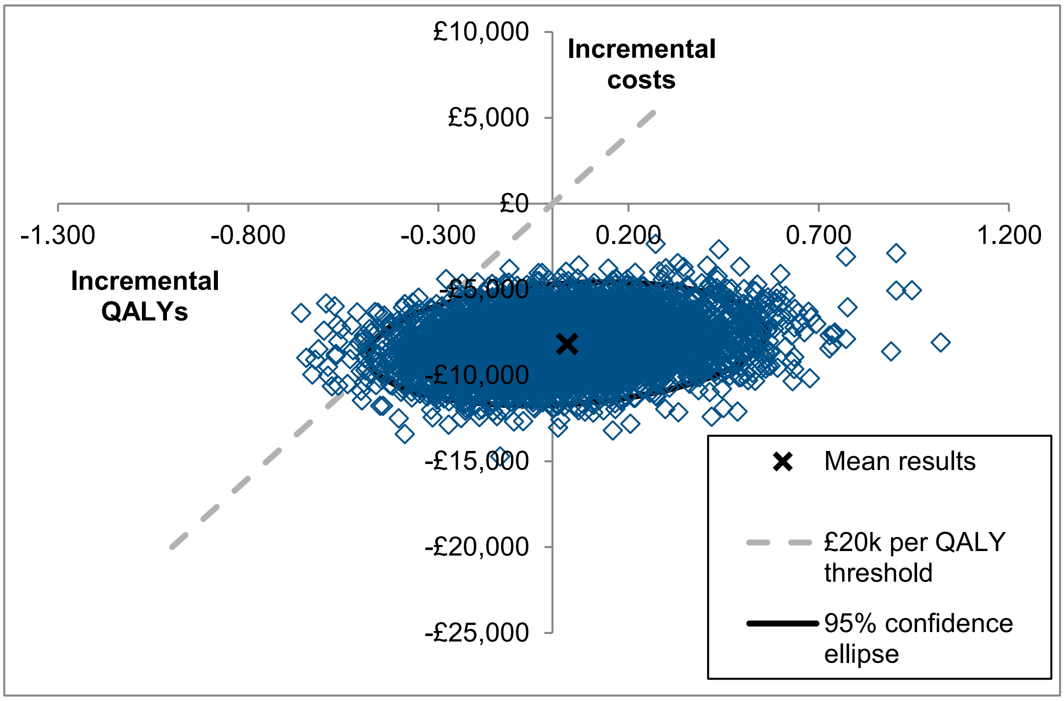


Figure 4: Cost effectiveness plane - scatter plot

1.3.2 Sensitivity analyses

A number of sensitivity analyses were conducted - Table 16. The incremental cost of laparoscopic lavage ranged from a saving of £12,500 per patient to a loss of £3,000. Incremental QALYs ranged from a loss of 0.44 to a gain of 0.26.

Laparoscopic lavage was the lowest cost strategy for all except one analysis. That was when it was assumed that all patients in the resection arm had primary anastomosis without diverting ileostomy. In this scenario, Resection dominated lavage. This is due to the lower mortality assumed after this procedure, zero reoperation rate and zero long term costs assumed. In a threshold analysis we found that lavage was cost saving compared with resection unless only 4.5% or fewer patients in the resection arm had Hartmann's procedure (rather than primary anastomosis).

There were a few scenarios where resection was more costly than lavage but had more QALYs:

- When year 1 probabilities were taken only from the SCANDIV trial.
- When the one-year resection rate after lavage increased to 50%.
- When it was assumed that there is no difference in mortality at one year
- When a quality of life decrement was applied.

With one exception, in these scenarios the increased QALYs associated with resection were not large enough to justify the extra cost. That is, they cost more than £20,000 per QALY gained. The exception was where a resection rate of 50% was assumed post-lavage – in this scenario, resection cost £19,600 per QALY gained.

Table 16: Results of sensitivity analyses

	Incremental cost	Incremental QALYs	Cost per QALY gained - Lavage vs resection	Cost per QALY gained - Resection vs lavage	Probability Lavage more effective	Probability lavage lower cost	Probability lavage cost effective (£20k per QALY)	Probability lavage cost effective (£30k per QALY)
Base case (probabilistic)	-8,162	0.0387	Lavage dominant		56.4%	100.0%	98.4%	93.5%
Base case (deterministic)	-8,181	0.0364	Lavage dominant					
Decision tree probabilities								
1. Decision tree probabilities - all 3 trials, pooled across arms	-8,114	0.2557	Dominant		95.7%	100.0%	100.0%	100.0%
2. Decision tree probabilities – SCANDIV only	-9,090	-0.0946	Ineffective	96,115	35.2%	100.0%	92.4%	79.9%
3. Decision tree probabilities – LADIES only	-4,170	0.1939	Dominant		71.7%	97.2%	90.1%	86.0%
4. Decision tree probabilities – from observational studies	-8,884	0.1685	Dominant		93.0%	100.0%	100.0%	100.0%
6. Resection arm - All Hartmann's procedure	-12,489	0.1145	Dominant		67.7%	100.0%	100.0%	99.3%
7. Resection arm - All anastomosis	2,971	-0.4431	Dominated		4.9%	4.3%	2.2%	2.6%
8. Resection arm - All anastomosis with diverting ileostomy	-3,215	0.0315	Dominant		46.0%	98.8%	61.9%	56.4%
9. Mortality RR=1 at one year	-8,218	-0.0537	Ineffective	152,984	40.3%	100.0%	94.7%	83.3%
10. Decision tree - Higher resection rate in lavage arm (50%)	-4,429	-0.2263	Ineffective	19,568	18.5%	99.9%	49.8%	37.4%
11. Decision tree - Higher stoma reversal rate (75%)	-6,415	0.0496	Dominant		57.8%	100.0%	96.3%	89.4%

	Incremental cost	Incremental QALYs	Cost per QALY gained - Lavage vs resection	Cost per QALY gained - Resection vs lavage	Probability Lavage more effective	Probability lavage lower cost	Probability lavage cost effective (£20k per QALY)	Probability lavage cost effective (£30k per QALY)
Markov model								
14. Markov model - Higher recurrence and resection rate, reflecting second episode of diverticulitis	-6,641	0.0063	Dominant		49.1%	100.0%	95.1%	86.7%
21. Markov model - Higher stoma reversal rate (x2)	-7,934	0.0420	Dominant		56.2%	100.0%	98.2%	93.2%
23. Longer time until reversal (12m colostomy, 6m ileostomy)	-9,183	0.0313	Dominant		54.5%	100.0%	99.2%	95.1%
Health outcomes								
12. Survival decrement for stoma	-8,060	0.1369	Dominant		71.0%	100.0%	98.9%	96.4%
13. Quality of life decrement for stoma	-8,171	0.1318	Dominant		71.1%	100.0%	99.1%	96.5%
20. Survival and quality of life decrement for stoma	-8,084	0.2217	Dominant		81.1%	100.0%	99.5%	98.1%
19. Quality of life decrement associated with morbidity	-8,199	-0.0497	Ineffective	165,046	38.8%	100.0%	96.9%	87.8%
Unit costs								
15. Lavage cost 50% higher	-6,230	0.0392	Dominant		56.0%	100.0%	95.2%	87.8%
16. Stoma cost 50% lower	-5,134	0.0346	Dominant		55.1%	100.0%	92.0%	83.9%
17. Stoma reversal cost 50% lower	-7,229	0.0341	Dominant		54.8%	100.0%	96.8%	90.2%
18. Readmission cost 50% higher	-8,042	0.0319	Dominant		54.7%	100.0%	98.0%	92.9%

1.4 Discussion

In the base case analysis, laparoscopic lavage dominated surgical resection for the treatment of perforated acute diverticulitis and purulent peritonitis; that is to say that it was more effective in terms of QALYs and it was cost saving.

In sensitivity analyses, it was cost saving in all but one analysis, which was when all patients in the resection arm had primary anastomosis without diverting ileostomy. In that analysis, lavage was dominated by resection.

In a number of other analyses, it was less effective than resection in terms of QALYs, but only in one scenario was the QALY loss large enough to offset the cost savings, at a threshold of £20,000 per QALY gained – when a resection rate of 50% was assumed.

The model was based on the results of the three included randomised trials. These trials were quite small and were heterogeneous in terms of surgery in particular. The follow-up was for one-year (two-years for one trial). Therefore, the long-term impact of the interventions is quite uncertain. There was a lack of long-term survival data, especially for lavage and hence we assumed that for lavage it was equivalent to patients undergoing primary anastomosis.

Not all the outcomes in the guideline review were modelled explicitly, since there was a lot of overlap between them, but they have been captured implicitly as follows:

- Abscess (favoured resection) - most would be treated surgically. In year 1 we have ensured the difference in operations seen in the trials was captured. In years 2-10, the patients transition to emergency resection based on cohort evidence – some of these will be due to an abscess
- Recurrence of diverticulitis (favoured resection). In years 2-10 we have explicitly modelled recurrence in the post-lavage arm but have for simplicity not modelled it in the stoma and post-anastomosis. For patients with recurrence there is a negative impact on quality of life and the cost of an admission is incurred.
- Unplanned readmissions (favoured resection). See Recurrence of diverticulitis.
- Morbidity/adverse events (favoured resection). We have ensured that the total difference in operations in year 1 has been explicitly modelled. For readmissions, see Recurrence of diverticulitis. In a sensitivity analysis, we applied a deficit in terms of quality of life to the proportion of patients that were recorded as having morbidity.

We did not find direct comparison of EQ-5D data in the trials. What quality of life evidence there was, did not show a difference between arms, yet there was significantly more morbidity reported. In the longer term, there could be quality of life improvement through reducing stoma formation. In terms of QALYs, the direction of effect seems to be quite sensitive to the assumptions made about quality of life.

1.4.1 Comparison with other studies

This study is an improvement on previous economic evaluations, since it uses data from all three included RCTs.

The findings of this analysis are in keeping with the two published economic evaluations. They found savings per patient of £8,000 and £18,000 respectively. Our base case savings of £8,200 are comparable and are perhaps an under-estimate, since where we made assumptions or simplified the model we tended to do so in such a way that favoured resection.

The published cost-utility analysis found resection to have slightly more QALYs but not enough to achieve an acceptable level of cost effectiveness. This was consistent with our sensitivity analysis that ascribed a utility decrement to patients with morbidity.

1.4.2 Evidence statement

- One original cost-utility analysis found that laparoscopic lavage was cost saving compared with resection for patients with perforated diverticulitis (£8000 saved per patient). This was rated as partially applicable with potentially serious limitations.

We have rated this analysis as having potentially serious limitations due to the uncertainty around impact on quality of life and survival.

1.4.3 Conclusions

This analysis found lavage to be cost saving compared with resection, since there were fewer re-operations and fewer people on long-term stoma.

The impact of QALYs gained is less clear. Lavage had fewer QALYs than resection in a number of sensitivity analyses and it was dominated by resection if it was assumed that 95% or more resections are primary anastomoses.

Overall, there is a lot of uncertainty because the three trials are relatively small and heterogeneous and there is little long-term evidence for lavage, especially in terms of survival and quality of life.

Based on the published and original economic evidence supporting laparoscopic lavage, the Committee decided to offer lavage as an alternative to resection. Given the uncertainty in the evidence base, it was decided that there is still a role for resection.

This recommendation is likely to lead to cost savings to the NHS, since laparoscopic lavage is not commonly conducted in the UK and therefore its more widespread use should lead to fewer operations and less people requiring long-term stoma care.

2 Supplement: Example WinBUGS code

2.1 12 month probability of resection after laparoscopic lavage, conditional on not dying

This code is adapted from Dias, Ades, Welton, Jansen and Sutton (2018) Network Meta-Analysis for Decision Making.

2.1.1 Fixed effects meta-analysis

```
# Binomial likelihood, logit link
# Baseline fixed effect model
model{                                    # *** PROGRAM STARTS
for (i in 1:ns){                          # LOOP THROUGH STUDIES
    r[i] ~ dbin(p[i],n[i])                # Likelihood
    logit(p[i]) <- m                      # Log-odds of response

# expected value of the numerators
    rhat[i] <- p[i] * n[i]
#Deviance contribution
    dev[i] <- 2 * (r[i] * (log(r[i])-log(rhat[i]))
             +  (n[i]-r[i]) * (log(n[i]-r[i]) - log(n[i]-rhat[i])))
  }
totresdev <- sum(dev[])                   # total residual deviance
m ~ dnorm(0,.0001)                        # vague prior for mean
logit(R) <- m                             # posterior probability of response
}
```

Data

list(ns=3) # ns=number of studies

r[] n[]
19 43
18 71
 7 0
END

Initial values
list(mu=c(0,0,0), sd.m=1, m=0)
list(mu = c(-1,-1,-1), sd.m=2, m= -1)
list(mu = c(1,2,1), sd.m = 0.5, m = 1)

2.1.2 Random effects meta-analysis

```
# Binomial likelihood, logit link
# Baseline random effects model
model{                                    # *** PROGRAM STARTS
for (i in 1:ns){                          # LOOP THROUGH STUDIES
    r[i] ~ dbin(p[i],n[i])                # Likelihood
    logit(p[i]) <- mu[i]                  # Log-odds of response
    mu[i] ~ dnorm(m,tau.m)                # Random effects model
  }
mu.new ~ dnorm(m,tau.m)                   # predictive dist. (log-odds)
m ~ dnorm(0,.0001)                        # vague prior for mean
var.m <- 1/tau.m                          # between-trial variance
```

```
tau.m <- pow(sd.m,-2)               # between-trial precision
  = (1/between-trial variance)
sd.m ~ dunif(0,5)               # vague prior for between-trial SD
#tau.m ~ dgamma(0.001,0.001)
#sd.m <- sqrt(var.m)
logit(R) <- m                   # posterior probability of response
logit(R.new) <- mu.new          # predictive probability of response
}
```

Data

list(ns=3) # ns=number of studies

```
r[]     n[]
19      43
18      71
 7      40
END
```

Initial values

list(m=0)

list(m= -1)

list(m = 1)

3 Supplement – Input parameters used in the probabilistic base case

Table 17: Probabilities, rate and utilities

Parameter	Mean	Standard error	Parameters of the beta distribution (except where stated)	
			alpha	beta
Decision tree - Resection arm				
Hartmann's as index intervention[(a)]	65.15%	0.04552	70.737	37.838
Proportion of anastomosis with diverting ileostomy	70.0%		14	6
Hartmann's reversed, conditional on not dying[(a)]	53.14%	0.05077	50.806	44.802
Death after Hartmann's[(a)]	14.08%	0.04109	9.948	60.704
Death after anastomosis	4.2%		1	23
Death prior to ileostomy reversal	14.3%		2	12
Decision tree - Lavage arm				
Death after lavage (no other interventions) [(a)]	5.52%	0.01788	8.956	153.233
Resection after lavage, conditional on not dying[(a)]	28.58%	0.03636	43.840	109.555
Hartmann's as re-intervention[(a)]	67.58%	0.07606	24.918	11.954
Proportion of anastomosis with diverting ileostomy	25.0%		3	9
Death after anastomosis	20.0%		2	8
Markov model – Mortality in acute states				
Hartmann's procedure	11.9%		65	480
Primary anastomosis	2.2%		17	754
Anastomosis with diverting ileostomy	9.8%		24	220

			Parameters of the beta distribution (except where stated)	
Parameter	**Mean**	**Standard error**	**alpha**	**beta**
Colostomy reversal	0.5%		11	2031
Ileostomy reversal	1.0%		50	5120
Markov model – Mortality by cycle				
1	4.9%		11	208
2	1.7%		4	205
3	2.3%		5	200
4	6.0%		12	188
5	3.2%		6	182
6	2.0%		4	179
7	3.3%		6	173
8	3.4%		6	167
9	0.0%		1	166
10	0.7%		1	165
11	3.6%		6	159
12	3.0%		5	155
13	0.0%		1	154
14	7.7%		12	143
15	0.0%		1	142
16	0.0%		1	142
17	4.2%		6	137
18	0.0%		1	136
Markov model – other probabilities				
Anastomotic leak with primary anastomosis	7.9%	0.0157	22.9	268.9

Parameter	Mean	Standard error	Parameters of the beta distribution (except where stated)	
			alpha	beta
Recurrence of diverticulitis (10 years)	22.0%		709	2,513
Later colostomy reversal (6 months) – Vennix(b)	1.77%	0.00353	24	1363
Later colostomy reversal (6 months) - Gehrman(b)	1.43%	0.00285	24	1699
Colostomy reversal success - Vennix(b)	93%	0.186	0.82	0.06172
Colostomy reversal success - Gehrman(b)	86%	0.172	2.64	0.429767
Recurrence – Gamma distribution	1.51	0.02	9,764	0
Utilities				
Hartmann’s procedure	0.67		50.92	25.08
Primary anastomoses	0.77		40.81	12.19

(a) Pooled using WinBUGS –see 1.2.3.1
(b) Using the method of moments and assuming the standard error is 20% of the mean.

Table 18: Decision tree outcome probabilities (Dirichlet distribution)

	Events	Probability
Outcome of stoma reversal (resection arm)		
Reversal success	28	93.3%
Reversal failure	1	3.3%
Death after reversal	1	3.3%
Outcome of Hartmann’s procedure (lavage arm)		
Hartmann's reversed	6	18.8%
Hartmann's not reversed	17	53.1%
Death after Hartmann's	9	28.1%

Table 19: NHS reference costs

Currency Code	Currency Description	Activity	National Average Unit Cost	Lower Quartile Unit Cost	Upper Quartile Unit Cost	Gamma distribution alpha	Gamma distribution beta
Introduction of substance into peritoneal cavity (Emergency)							
Non-Elective Long Stay Data							
FF52A	Intermediate Therapeutic General Abdominal Procedures, 19 years and over, with CC Score 3+	389	£6,259	£4,559	£7,200	10	613
FF52B	Intermediate Therapeutic General Abdominal Procedures, 19 years and over, with CC Score 1-2	524	£4,228	£3,323	£4,924	13	333
FF52C	Intermediate Therapeutic General Abdominal Procedures, 19 years and over, with CC Score 0	585	£3,488	£2,833	£3,964	17	202
Excess Bed Day HRG Data							
FF52A	Intermediate Therapeutic General Abdominal Procedures, 19 years and over, with CC Score 3+	940	£337	£248	£401	9	38
FF52B	Intermediate Therapeutic General Abdominal Procedures, 19 years and over, with CC Score 1-2	255	£230	£130	£279	4	54
FF52C	Intermediate Therapeutic General Abdominal Procedures, 19 years and over, with CC Score 0	339	£321	£247	£408	7	44
Non-Elective Short Stay Data							
FF52A	Intermediate Therapeutic General Abdominal Procedures, 19 years and over, with CC Score 3+	100	£2,026	£760	£2,921	2	1267
FF52B	Intermediate Therapeutic General Abdominal Procedures, 19 years and over, with CC Score 1-2	162	£1,360	£587	£1,890	2	686
FF52C	Intermediate Therapeutic General Abdominal Procedures, 19 years and over, with CC Score 0	291	£1,317	£847	£1,674	5	285
Sigmoid colectomy and ileostomy HFQ (Emergency)							
Non-Elective Long Stay Data							
FF31A	Complex Large Intestine Procedures, 19 years and over, with CC Score 9+	876	£12,532	£9,565	£14,759	11	1183
FF31B	Complex Large Intestine Procedures, 19 years and over,	1,116	£10,027	£7,489	£11,546	11	902

Currency Code	Currency Description	Activity	National Average Unit Cost	Lower Quartile Unit Cost	Upper Quartile Unit Cost	Gamma distribution alpha	Gamma distribution beta
	with CC Score 6-8						
FF31C	Complex Large Intestine Procedures, 19 years and over, with CC Score 3-5	1,930	£8,597	£6,844	£9,589	18	482
FF31D	Complex Large Intestine Procedures, 19 years and over, with CC Score 0-2	2,783	£7,314	£5,934	£8,112	21	356
Excess Bed Day HRG Data							
FF31A	Complex Large Intestine Procedures, 19 years and over, with CC Score 9+	1,668	£323	£227	£344	14	23
FF31B	Complex Large Intestine Procedures, 19 years and over, with CC Score 6-8	2,215	£339	£244	£390	10	34
FF31C	Complex Large Intestine Procedures, 19 years and over, with CC Score 3-5	2,932	£292	£197	£355	6	47
FF31D	Complex Large Intestine Procedures, 19 years and over, with CC Score 0-2	2,614	£321	£258	£384	12	27
Non-Elective Short Stay Data							
FF31A	Complex Large Intestine Procedures, 19 years and over, with CC Score 9+	255	£4,374	£2,339	£5,477	4	1237
FF31B	Complex Large Intestine Procedures, 19 years and over, with CC Score 6-8	289	£4,097	£2,421	£5,177	4	1019
FF31C	Complex Large Intestine Procedures, 19 years and over, with CC Score 3-5	475	£3,565	£2,413	£4,506	5	675
FF31D	Complex Large Intestine Procedures, 19 years and over, with CC Score 0-2	588	£3,907	£2,845	£4,657	8	461
Sigmoid colectomy and anastomosis HEQ (Emergency)							
Non-Elective Long Stay Data							
FF33A	Distal Colon Procedures, 19 years and over, with CC Score 3+	155	£8,507	£5,953	£10,265	7	1201
FF33B	Distal Colon Procedures, 19 years and over, with CC Score 0-2	250	£6,176	£4,672	£7,439	9	681

Currency Code	Currency Description	Activity	National Average Unit Cost	Lower Quartile Unit Cost	Upper Quartile Unit Cost	Gamma distribution alpha	Gamma distribution beta
Excess Bed Day HRG Data							
FF33A	Distal Colon Procedures, 19 years and over, with CC Score 3+	327	£347	£273	£355	33	11
FF33B	Distal Colon Procedures, 19 years and over, with CC Score 0-2	275	£334	£284	£416	12	28
Non-Elective Short Stay Data							
FF33A	Distal Colon Procedures, 19 years and over, with CC Score 3+	29	£4,003	£2,757	£4,480	10	408
FF33B	Distal Colon Procedures, 19 years and over, with CC Score 0-2	31	£3,653	£2,462	£4,592	5	683
Sigmoid colectomy and anastomosis NEC (Elective)							
Elective Long stay data							
FF33A	Distal Colon Procedures, 19 years and over, with CC Score 3+	592	£7,558	£5,677	£8,628	12	633
FF33B	Distal Colon Procedures, 19 years and over, with CC Score 0-2	2,029	£6,104	£4,994	£7,113	15	404
Excess Bed Day HRG Data							
FF33A	Distal Colon Procedures, 19 years and over, with CC Score 3+	107	£405	£260	£327	68	6
FF33B	Distal Colon Procedures, 19 years and over, with CC Score 0-2	360	£281	£133	£374	2	114
Ileostomy closure (Elective)							
Elective Long stay							
FF22A	Major Small Intestine Procedures, 19 years and over, with CC Score 7+	214	£9,813	£6,450	£11,842	6	1628
FF22B	Major Small Intestine Procedures, 19 years and over, with CC Score 4-6	817	£6,554	£5,062	£7,843	10	648
FF22C	Major Small Intestine Procedures, 19 years and over,	1,930	£5,080	£4,107	£5,634	20	252

Currency Code	Currency Description	Activity	National Average Unit Cost	Lower Quartile Unit Cost	Upper Quartile Unit Cost	Gamma distribution alpha	Gamma distribution beta
	with CC Score 2-3						
FF22D	Major Small Intestine Procedures, 19 years and over, with CC Score 0-1	2,773	£4,186	£3,497	£4,623	25	167
Excess Bed Day HRG Data							
FF22A	Major Small Intestine Procedures, 19 years and over, with CC Score 7+	340	£433	£284	£647	3	166
FF22B	Major Small Intestine Procedures, 19 years and over, with CC Score 4-6	399	£366	£303	£341	171	2
FF22C	Major Small Intestine Procedures, 19 years and over, with CC Score 2-3	775	£338	£212	£391	6	52
FF22D	Major Small Intestine Procedures, 19 years and over, with CC Score 0-1	354	£322	£255	£388	11	30
Outpatient visits							
N24AF	Specialist Nursing, Stoma Care Services, Adult, Face to face	48,609	£51	£28	£56	6	8
N24AN	Specialist Nursing, Stoma Care Services, Adult, Non face to face	17,527	£23	£18	£24	27	1
104	Colorectal Surgery	277,810	£112	£75	£145	5	24
FE32Z	Diagnostic Colonoscopy, 19 years and over	2,614	£469	£150	£588	2	224

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