



A cost-minimization analysis of first intention laparoscopic compared to open right hemicolectomy for colon cancer



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HIGHLIGHTS

- Morbidity, mortality and survival were equivalent.
- Total theatre cost was €643 ± 256 higher in the laparoscopic group.
- The reduced LOS in the laparoscopic group saved €1960 ± 636/patient.
- Overall first intention laparoscopic right hemicolectomies saved €1316 ± 733/patient.

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ABSTRACT

Background: The morbidity, mortality and survival following a laparoscopic right hemicolectomy for colon cancer are equivalent to an open operation. However, the cost of a longer operating time and consumables may offset savings from a shorter length of stay (LOS). A cost minimization study was undertaken to compare the relative costs.

Methods: A retrospective cohort study of consecutive elective right hemicolectomies for colon cancer performed over 5 years by two teams. One team performed an open operation (OG), the other intended to perform all operations laparoscopically (LG). Clinical outcomes and relative costs were evaluated. Results expressed as mean ± SEM.

Results: There were 58 patients in the open group and 56 in the first intention laparoscopic group, of which 77% were completed laparoscopically. There was no difference in age, gender or cancer stage. The complications, mortality and 5-year survival were similar. Anaesthetic (LG = 63 ± 3, OG = 62 ± 2 min) and surgical times (LG = 144 ± 8, OG = 143 ± 5 min) were similar. Consumables cost €571 more and the total theatre cost was €643 ± 256 higher in the laparoscopic group compared with the open group ($p = 0.01$). The LOS in the laparoscopic group (4.6 ± 0.5 days) was less than in the open group (8.3 ± 1 days, $p < 0.01$) saving €1960 ± 636 per patient. Overall, first intention laparoscopic right hemicolectomies saved €1316 ± 733 per patient. A probability sensitivity analysis indicated a 62% probability that a laparoscopic right hemicolectomy was cheaper than an open operation.

Conclusion: Laparoscopic right hemicolectomy is oncologically equivalent but less costly and should be considered the procedure of choice for right-sided colon cancer unless contraindicated.

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1. Introduction

Colorectal cancer is the fourth most common cancer in the UK with 41581 new cases diagnosed in 2011. About 25% of colorectal cancers occur in the proximal colon and most are treated with a

right hemicolectomy [1]. An open right hemicolectomy is currently the standard operation but an increasing number of operations are performed laparoscopically. The post-operative mortality is similar and the long-term survival after laparoscopic right hemicolectomies is as good as after open surgery [2–7]. Laparoscopic surgery has the advantage that it is less invasive than open surgery and, for most operations, is associated with fewer post-operative complications. However, it is uncertain whether this applies to right hemicolectomies. Some studies have shown that post-operative morbidity is reduced compared with open right

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hemicolectomies [2,6–10], but others have not shown any difference [5,11–13]. This indicates that there is little difference in outcome for a patient whether a right hemicolectomy is performed open or laparoscopically.

There is no doubt that the length of stay (LOS) after laparoscopic surgery is shorter than after open surgery suggesting that laparoscopic right hemicolectomies may save money. However, the reduced LOS following the implementation of enhanced recovery protocols has made the benefit of laparoscopic surgery less compelling [2,3,14]. In addition, laparoscopic right hemicolectomies take longer than open operations [8,10,14,15] and use more consumables [10,15,16]. To further complicate an economic evaluation not all operations can be completed laparoscopically and it is likely that operations in excluded patients are technically more difficult, take longer, have more post-operative complications and a longer hospital stay. As a consequence the higher theatre costs of a first intention to undertake right hemicolectomies laparoscopically may offset savings made from a reduced LOS. To investigate this we undertook an economic evaluation of a first intention to treat laparoscopic right hemicolectomy compared with an open operation. A cost minimization study from the healthcare system perspective was performed [17]. Cost minimization analysis was selected because outcomes of laparoscopic compared to open right hemicolectomy for colon cancer are equivalent.

2. Methods

A retrospective cohort study was undertaken of consecutive right hemicolectomies for colon cancer performed by two surgical teams at the Royal Cornwall Hospital (a District General Hospital) over a 5-year period between 2006 and 2011. Patients were referred from primary care to one or other of the surgical teams. The hospital does not get tertiary referrals. Patients were identified from a prospectively collected cancer database and double-checked by reviewing histopathology and operating theatre records. Where necessary the medical records were reviewed. Patients excluded from this study comprised emergency right hemicolectomies and non-cancer operations. All patients had a pre-operative colonoscopy and staging CT scan of the chest, abdomen and pelvis. At the colonoscopy a tattoo was placed 5 cm distal to the tumour unless the colonoscopy was incomplete. A consultant or senior colorectal trainee assisted by the consultant undertook all operations. All patients operated on by one team had a conventional open right hemicolectomy (OG). After 2006 the other surgical team attempted to undertake all elective right hemicolectomies laparoscopically: the “laparoscopic” group (LG). In some patients in the first intention laparoscopic group the operation was converted to an open operation after either a diagnostic laparoscopy (strategic conversion) or a period of dissection (reactive conversion).

Patients were cared for on the same ward by the same team, which included 3 junior doctors and an enhanced recovery nurse all adhering to similar post-operative protocols. Cornwall has a stable population allowing long-term follow up of patients. Patients were followed up in the out patient clinic for a minimum of 5 years. The following data were collected on each patient: age, gender, date of operation, operation details, histology, post-operative complications, date of discharge and, if dead, the date of death and cause of death.

2.1. Surgical technique

Open right hemicolectomies were performed through a midline or transverse incision using a standard technique. All patients in the laparoscopic group initially underwent a diagnostic laparoscopy and trial dissection to assess suitability for a laparoscopic resection.

Laparoscopic right hemicolectomies were performed using a 4-port technique including two disposable 5 mm ports; a Lotus™ ultrasonic scalpel (SRA Developments Ltd) and major vessels were divided between disposable titanium clips. The specimen was retrieved through a transverse incision in the right upper quadrant. The anastomosis in both laparoscopic and open right hemicolectomies was usually hand sewn extra-corporeally.

2.2. Cost estimations

All costs are given in Euros, 2014 level at a conversion rate of £1 = €1.30. Cost estimations were based on the duration of the operation, the cost of consumables and the LOS. The consumables did not change during the course of the study. Operating times and consumable costs were collected using galaxy (Galaxy™) operating department software. The procedure time was the time an anaesthetic started to the time the patient was taken into recovery. Surgical time was the time from the start of the operation to the time it finished. Anaesthetic time was procedure time minus surgical time. The estimated cost of an elective operating theatre in the UK is about €1560 per hour, or €26/minute. The estimated average cost for a ward bed was €520 per day, and €1950 per day for an intensive care unit (ICU) bed.

2.3. Data collection and analysis

Data on all resections was collected on a Microsoft Excel™ spreadsheet (Microsoft Corporation). Results are expressed as mean ± SEM or with 95% confidence intervals quoted in parentheses. Results were analysed on an intention to treat principle. Descriptive statistics and statistical analysis was undertaken using Graph Pad Prism™ (GraphPad Prism 6™, GraphPad Software). Fisher's exact test was used to analyse contingency tables, Mann–Whitney test to compare 2 groups and Kruskal Wallis test to compare 3 or more groups. Survival curves were created and compared using the Kaplan Meier method. The level of significance was $P < 0.05$.

For the post hoc cost minimization analysis it was assumed that the clinical outcome measures (morbidity, mortality and survival) were similar in both groups. Incremental cost was calculated as the difference between the costs of the operation divided by the difference in LOS. To assess the likelihood of first intention laparoscopic right hemicolectomies resulting in lower costs than open operations a non-parametric bootstrapping approach was used. Procedure data was stored in the following arrays from where they were re-sampled randomly 10,000 times:

- $S_{j,k}$ the surgical time for operation j (minutes)
- $A_{j,k}$ the anaesthetics time for operation j (minutes)
- $C_{j,k}$ the monetary value of the consumables used in operation j (Euros)
- $L_{j,k}$ the postoperative length of stay in a non-ICU hospital ward (days)
- $T_{j,k}$ the postoperative length of stay in ICU (days)

The index “ j ” ran from 1 through 56 for laparoscopic operations and from 1 to 58 for open operations. The variable k held the value 1 for the first intention laparoscopic right hemicolectomies and 2 for the open operations.

The cost of each of 10,000 bootstrapped procedures was obtained by taking random samples from each of the variable arrays and feeding into the following equations:

$$R_1 = 26(s_j, 1 + a_j, 1) + c_j, 1 + 520l_j, 1 \\ + 1950t_j, 1, \text{ where the random variable, } j \in Z\{1, 56\}$$

$$R_0 = 26(s_j, 2 + a_j, 2) + c_j, 2 + 520l_j, 2 \\ + 1950t_j, 2, \text{ where the random variable, } j \in Z\{1, 58\}$$

The variables R_1 and R_0 represented the cost of each of the 10,000 procedures bootstrapped to be first intention laparoscopic or open right hemicolectomies. Numerically, j was free to take a different value when sampling each variable comprising the costs R_1 and R_0 . Financially the benefit of laparoscopic over open procedures was then represented as R_1 minus R_0 .

3. Results

There were 56 patients in the first intention laparoscopic right hemicolectomy group and 58 in the open group. The results are summarized in Table 1. There was no significant difference in age (LG = 74 ± 1 years, OG = 77 ± 1 years, $p = 0.1$), gender (LG = 46% males, OG = 43%) or stage distribution between groups. There was no difference in 30-day and 90-day mortality (LG = 1.8%, OG = 3%) but the only death in the first intention laparoscopic group occurred after conversion to an open operation. The complication rate in the first intention laparoscopic right hemicolectomy group was 14%, compared with 22% in the open group ($p = 0.1$). In the first intention laparoscopic right hemicolectomy group 23% were converted to an open operation (10 strategic and 3 reactive conversions).

The median follow up was 4.8 years (range 3.8–9 years). There was no difference in disease free 5-year survival (LG = 78 ± 6% compared with OG = 67 ± 7%, hazard ratio 1.4, $p = 0.3$). The 5-year survival of the subset of laparoscopic right hemicolectomies in the first intention laparoscopic group (77 ± 7%) was not significantly different from open right hemicolectomies (hazard ratio 1.3,

$p = 0.3$). There was no difference in disease free survival among patients with advanced disease. The 5-year survival in patients' with stage II disease was 73 ± 7% in the first intention laparoscopic group compared with 66 ± 7% in the open group (hazard ratio 1.2, $p = 0.3$). The 5-year survival in patients with stage III and IV disease was 59 ± 11% in the first intention laparoscopic group compared with 55 ± 11% in the open group (hazard ratio 1, $p = 1$). There was no difference when the subset of laparoscopic right hemicolectomies was compared with open operations (Stage II 71 ± 9%, hazard ratio 1, $p = 0.8$; stage III and IV 62 ± 11%, hazard ratio 1.1, $p = 0.8$).

3.1. Procedure times and LOS

The procedure times are summarized in Table 2. There was no difference in the time taken to give the anaesthetic ($p = 0.9$), the surgical time ($p = 0.7$) or the total procedure times ($p = 0.8$) between the first intention laparoscopic and the open right hemicolectomy groups. The LOS in the first intention laparoscopic group was 4.6 ± 0.5 days (median 3.5 days, range 1–22 days), nearly 4 days less than in the open group (median 7 days, range 3–42 days, $p = 0.0004$). The reduced LOS was because the LOS after right hemicolectomies completed laparoscopically (3.7 ± 1 days) was less than after open right hemicolectomies (8.3 ± 1 days $p = 0.0001$). The sub-group of 13 patients whose operations were converted to an open right hemicolectomy following an attempted laparoscopic operation had a similar LOS (7.3 ± 1 days) to patients in the open right hemicolectomy group ($p = 0.6$).

3.2. Economic evaluation

In the first intention laparoscopic right hemicolectomy group the operation cost (€5384 ± 206) was similar to the open operation (€5334 ± 135, $p = 0.8$). However, the consumables used in the first intention laparoscopic group (€1157 ± 40) cost €571 more than in the open group so that the total theatre cost in the first intention

Table 1
Patient characteristics.

	Open right hemicolectomy	Intention to treat laparoscopically	<i>p</i> value
Number	58	56	
Age (years)	77 ± 1.2	74 ± 1.3	0.1
Males (%)	25 (43%)	26 (46%)	0.9
Cancer stage			
T stage 1:2:3:4	1:5:31:21	3:11:28:14	>0.2
TxN1 M0	16	15	1
TxNxM1	10	9	1
Deaths (%)	2 (3%)	1 (1.8%)	1
LOS (days)	8.3 ± 1	4.6 ± 0.5	0.0004
Intensive care stay (days)	10	8	1
Complications			
Morbidity (%)	13 (22%)	8 (14%)	0.1
Multiple organ failure	0	1	
Anastomotic leak	2	1	
Pulmonary Embolus	1	0	
Pneumonia	4	0	
Atrial Fibrillation	0	1	
Acute renal failure	1	0	
Ileus	3	3	
Abscess	1	1	
Wound infection	2	1	
Wound dehiscence	1	0	
Haemorrhage	0	1	
Blood transfusion	1	1	
5 year survival			
Disease free survival	67 ± 7%	78 ± 6%	0.3
Stage II	66 ± 7%	73 ± 7%	0.3
Stage III and IV	55 ± 11%	59 ± 11%	1

Table 2
Procedure times and cost comparisons.

	Open right hemicolectomy		Intention to treat laparoscopically		<i>p</i>
	Duration	Cost	Duration	Cost	
Anaesthetic	62 ± 2 min	€1618 ± 45	63 ± 3 min	€1634 ± 75	0.9
Surgery	143 ± 5 min	€3716 ± 125	144 ± 8 min	€3751 ± 196	0.9
Operation	205 ± 5 min	€5334 ± 134	207 ± 8 min	€5384 ± 206	0.8
Consumables		€586		€1157	0.01
Total theatre cost		€5920 ± 135		€6563 ± 220	0.01
LOS	8.3 ± 1 days	€4551 ± 515	4.6 ± 0.5 days	€2581 ± 367	0.01
Total cost		€10461 ± 583		€9145 ± 438	0.06

laparoscopic group (€6563 ± 220) was €643 ± 256 more than in the open group (€5920 ± 135, $p = 0.01$). A probability sensitivity analysis of 10000 bootstrapped samples showed that the total theatre cost of undertaking laparoscopic right hemicolectomies was more than that of the open procedure in 64% of cases.

The savings from the reduced LOS in the first intention laparoscopic group were €1960 ± 636 per patient ($p = 0.0004$). The total cost (theatre cost plus LOS cost) of an intention to undertake a right hemicolectomy laparoscopically (€9145 ± 438) was €1316 ± 733 less per patient than an open operation (€10461 ± 583, $p = 0.06$). Bootstrapping analysis indicated the total cost of a first intention laparoscopic right hemicolectomy (€9152 ± 30) was €1284 ± 51 less than an open operation (€10436 ± 41, $p < 0.0001$). A probability sensitivity analysis of 10,000 bootstrapped procedures indicated a 62% probability that a laparoscopic right hemicolectomy was cheaper than an open operation (Fig. 1).

The subgroup of right hemicolectomies completed laparoscopically (total cost = €8818 ± 132) saved €1643 ± 818 per patient compared with open operations ($p = 0.005$). The cost when first intention laparoscopic operations were converted (total cost = €10224 ± 615) was similar to the cost of an open operation ($p = 0.8$) but more expensive than operations completed laparoscopically ($p = 0.01$).

A first intention to undertake right hemicolectomies laparoscopically is only cost effective when the average procedure time is 43.6 min less than in the open group (95% confidence intervals 20–83 min). Similarly, laparoscopic right hemicolectomies are only cost effective if the excess cost of consumables (compared to an

open operation) is less than €2403 (95% confidence intervals €814 to infinity). The total theatre cost of first intention laparoscopic right hemicolectomies was €2555 ± 253 per in-patient day compared with €925.3 ± 51 per day for open operations ($p < 0.0001$). A first intention to undertake right hemicolectomies laparoscopically is only cost effective if the average LOS is 1.7 days less than open surgery (95% confidence intervals –2.6 to –0.6 days).

4. Discussion

Our findings show that first intention laparoscopic right hemicolectomy is less costly than the open procedure. Importantly, there was no difference in post-operative morbidity, 30-day or 90-day mortality, long-term disease free survival, or survival in the subgroup of patients presenting with advanced disease. This has previously been reported [2–7,9,16,18] but was important to demonstrate for a cost minimization analysis to be performed [17]. Previous studies have shown that patients benefit from the laparoscopic approach because it is less invasive with a shorter recovery time [2,3]. In this study the LOS in the first intention laparoscopic right hemicolectomy group was 4.6 days, almost half that of open surgery and similar or less than other published series including those with enhanced recovery protocols [5–10,16,18–20]. Consequently the post-operative in-patient savings were €1960 ± 636 in the first intention laparoscopic group compared to the open group. However, it is uncertain whether or not a first intention laparoscopic right hemicolectomy is economically advantageous for the

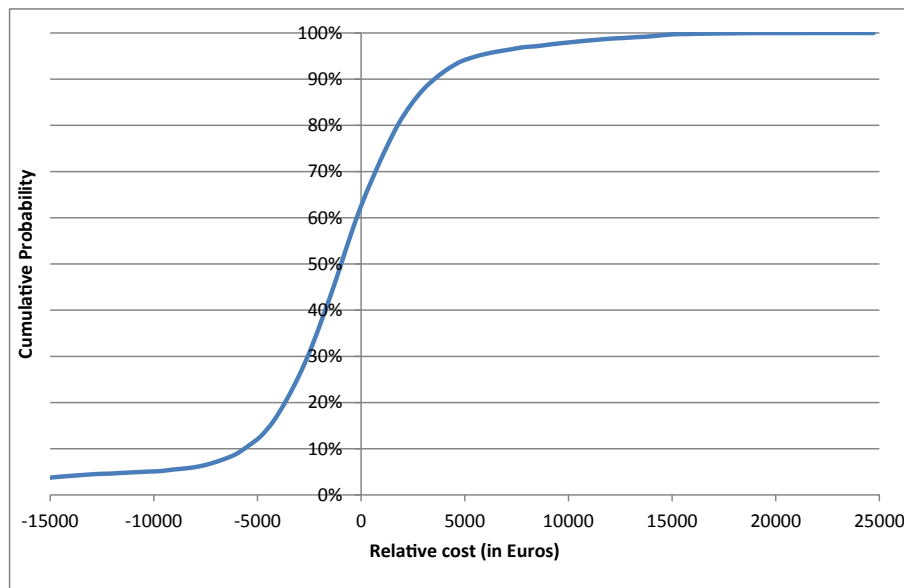


Fig. 1. The cumulative probability that the relative cost of first intention laparoscopic right hemicolectomy is less than an open procedure.

health care system because the savings made from a shorter LOS may be offset by a longer procedure time and higher cost of consumables [10,15,16].

This study focused on two operating room costs for the cost minimization analysis: the cost of the theatre time and the cost of disposables used. In the UK the cost of an elective operating theatre is about €1560 per hour (€26 per minute). In previous published series, right hemicolectomies completed laparoscopically took longer than open operations making the theatre costs significantly higher [8,16,18]. In this series, the total procedure time was similar between the first intention laparoscopic and the open right hemicolectomy groups. However, laparoscopic procedures use more consumables, and more expensive consumables, than open operations [10]. In this study the cost of consumables used to undertake a laparoscopic right hemicolectomy was on average €571 more than those used in open surgery, similar to previous studies [10,21–25]. This cost difference will be greater if more, or more expensive disposable equipment is used. As a consequence the total theatre cost of a first intention laparoscopic right hemicolectomy was €643 ± 256 more than for an open operation. Bootstrapping indicated a 64% probability that the total theatre cost of a first intention laparoscopic right hemicolectomy was more expensive than an open procedure.

The post-operative in-patient cost in the first intention laparoscopic group was €1960 ± 636 less than in the open group. This saving offset the higher theatre costs so that the overall savings in the first intention laparoscopic right hemicolectomy group were on average €1316 per patient. Bootstrapping indicated there was a 62% probability that a first intention laparoscopic right hemicolectomy saved money for the health care provider. However, the longer the operation takes, or the more consumables used, the more expensive it is [10,15,16]. Sub-dividing this analysis, if operations in the first intention laparoscopic group take 45 min or more longer than open operations, or if the cost of consumables used is €2403 more than for open operations, the additional cost of the procedure offsets savings made from a reduced LOS. Similarly, first intention laparoscopic right hemicolectomies are only cost effective if the LOS is at least 1.7 days less than open operations. As a rule of thumb the cost of 20 min operating time is equivalent to 1 day of in-patient stay.

Initial studies indicated that because laparoscopic operations took longer and used more consumables they cost significantly more than open operations [10,21,22]. This raised the question as to whether the short-term benefits are worth the extra cost and suggested further studies are needed. More recent studies have demonstrated that laparoscopic colorectal surgery not only saves money for the health care system but also is cost effective at <\$50,000 per quality adjusted life year [15,23,24]. This study adds further support to the evidence that laparoscopic surgery saves money compared to open operations.

The authors acknowledge this is a retrospective study and may be underpowered to demonstrate small difference in outcomes. However, the patients in this study were consecutive, unselected referrals from primary care to one or other of two surgical teams. There was no difference in age, gender or cancer stage between groups suggesting they were similar. Furthermore, the outcomes were similar to those reported in other series including prospectively randomised controlled trials. The procedure times and LOS were accurately measured but the costs were estimated and therefore they are only indicative of relative costs. A detailed cost assessment would have been preferable but this was not possible in a retrospective study.

In conclusion, given the known oncologic equivalence of laparoscopic and open right hemicolectomy for colon cancer, this cost-minimization analysis demonstrates the cost savings to the

healthcare system of first intention laparoscopic compared to open right hemicolectomy due to shorter LOS despite extra theatre costs. As such, laparoscopic right hemicolectomy is oncologically equivalent but less costly and should be considered the procedure of choice for right-sided colon cancer unless contraindicated.

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Author contribution

Conception and design was by ALW. All authors undertook the literature review, contributed to data collection, checking and analysis, drafting and revising the article. ALW was the principal author and final approver.

Conflicts of interest

None.

Guarantor

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