

**Cost savings for elective laparoscopic resection compared with open resection for colorectal cancer in a region of high uptake**

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Published

2014

Journal Title

Surgical Endoscopy

DOI

[10.1007/s00464-013-3345-1](https://doi.org/10.1007/s00464-013-3345-1)

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Manuscript Title: Cost-savings for elective laparoscopic resection compared with open resection for colorectal cancer in a region of high-uptake.

Running Head: Costs of laparoscopic bowel cancer resection.

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## Abstract

### Background

Previous cost analyses on laparoscopic resection for colorectal cancer (CRC) reported slightly higher or similar costs, compared to open resection. These were based on randomised controlled trials when the laparoscopic approach was newly adopted.

This study compares costs for laparoscopic versus open resection in a region of high uptake where adoption is mature.

### Methods

Hospital costing data was obtained for elective resections for CRC between June 2009 and June 2011 in public hospitals in Queensland, Australia. The primary outcome was total costs; secondary outcomes were length-of-stay, operating time and ICU admission. Multivariate least-squares regression was used to adjust for potential confounders: age, sex, co-morbidities, procedure and hospital volume.

### Results

The crude mean cost for laparoscopic versus open resection was €20 036 versus €22 780 (difference: €2 744). Patients having laparoscopic resection (744/1 397; 53%) were slightly younger and had fewer co-morbidities (decreasing costs), but more had rectal surgery (increasing costs). The adjusted mean cost for laparoscopic resection was €20 396 versus €22 442 for open (difference: €2 054). Compared to open resection, when adjusted for potential confounders, laparoscopic resection resulted in similar duration of surgery (216 versus 214 minutes), shorter length-of-stay (difference: -1.1 days: 95%CI -1.9, -0.3) and shorter admissions to ICU (difference: -7.3 hours: 95%CI -11.9, -2.7).

### Conclusions

This non-randomised study in a region of high uptake, found similar operating times and lower cost for laparoscopic resection for CRC due to shorter length-of-stay and ICU admissions. Laparoscopic resection for CRC produces cost-savings when the procedure is widely adopted and surgeons are experienced in the technique.

Keywords: Colorectal cancer, laparoscopic resection, cost comparison, population-based data

## INTRODUCTION

High-quality evidence from randomised controlled trials (RCTs) shows that, compared with open resection, laparoscopic resection for colorectal cancer (CRC) results in less intra-operative blood loss, less post-operative pain, faster return of bowel function, shorter length-of-stay(1, 2) and lower risk of thrombo-embolism.(2) Clinical effectiveness is essential for the adoption of new technology in healthcare; however, healthcare administrators must consider the economic value of new technologies. Published analyses have reported that the cost of laparoscopic resection for CRC is similar or slightly greater than the costs for open resection.(3-7) While fewer complications and shorter length of hospital stay result in reduced costs, previous studies have reported increased costs associated with the specialised equipment required for laparoscopic resection; and increased costs associated with longer operating times.(8) For example, the Australasian Laparoscopic Colon Cancer Study (ALCCaS) reported an increased cost of disposable equipment in theatre of \$AU274.(7) Similar additional costs have been reported in the United States (US)(9) and United Kingdom (UK)(4). Franks *et al* (2006) reported longer operating time for laparoscopic resections of CRC leading to increased costs for theatre staff of £114 per operation in the UK.(4)

Cost analyses of laparoscopic resection for CRC, to date, have been predominantly based on RCTs when the procedures were performed in the early stage of adoption of laparoscopic resection for CRC. As the level of experience, patient selection, techniques and equipment for surgical procedures change over time, so too do the associated costs. For example, patients excluded from the RCTs in the early 1990s are now routinely considered for laparoscopic resection; specifically resections for

rectal cancer which are known to be more expensive than for colon cancer(10). Also, with experience, the operating time for laparoscopic resection can be similar to that of open resection.(11) It is therefore possible that, as uptake moves from the innovators to early-adopters and onto early/late majority,(12) the increased cost associated with longer operating time for laparoscopic resection of CRC will be diminished, and may even result in cost saving compared with open resection.

Queensland is the third largest state of Australia with a population of 4.6 million. Surgeons in Queensland were early-adopters of laparoscopic resection for CRC(13) and adoption has been faster than in any other state in Australia(14) and faster than most other jurisdictions around the world(15-17). Training courses in laparoscopic resection of the colon and rectum were run by a group of colorectal surgeons in Queensland during the early 2000s, providing experience in this technique to surgeons in the early period of adoption. Currently, more than 50% of resections for CRC in public hospitals in Queensland are laparoscopic. This study includes all CRC patients admitted to public hospitals for an elective resection of the colon or rectum, and provides a 'real world' cost assessment on unselected patients. The specific research question is: what are the differences in total and component (e.g. theatre, ICU) costs for laparoscopic versus open resection for CRC in a region with high uptake?

## **Methods**

### *Data*

This study was based on data drawn from the statewide Transition II Clinical Costing database with standardised feeder systems and process. It's main role is to support activity based funding and it is also regularly used by researchers to undertake cost studies.(18) It is a comprehensive collation of cost information associated with the provision of services to individual patients treated in public hospitals including resource utilisation in the operating theatre, anaesthetics, pharmacy, pathology, clinical imaging and other allied health resources, as well as general resources associated with a hospital admission and stay on the hospital ward, and the hospital administration. It does not include costs associated with surgical training outside of the operating theatre.

Transition II collects information for public hospitals, where patients receive treatment without any out-of-pocket costs. Resections performed in private hospitals, where the cost of treatment is covered by a combination of government subsidy, private health insurance, and patient payments, were excluded. About 60% of CRC patients in Queensland are treated in private hospitals; this paper focuses on the remaining 40% in public hospitals.

Total cost of the index admission for resection was obtained from Transition II for 1 273 out of 1 391 patients (92%). Component costs of interest included: theatre, anaesthetics, pharmacy, clinical imaging and pathology; these were obtained for 1 315 out of 1 391 patients (95%).

Patient level cost data in Transition II is a collation of: costs specific to the care of an individual patient, average cost of resources associated with admission, and standard daily costs. For instance; staff in the operating theatre is costed for an individual patient (cost allocated for each clinician (surgeons and nursing) multiplied by the number of minutes spent in the operating theatre), as is costs associated with anaesthesia and disposable surgical equipment (single use; such as the Harmonic scalpel). The cost of clinical consumables is based on the average cost specific to the surgical procedure. Costs associated with stays in the hospital ward are set at a per diem or per shift rate and include cost such as laundry and meals. Admissions to ICU are allocated at a standard cost per minute per patient.

The de-identified, unit-record data from Transition II was for the period June 2009 to June 2011. Data extraction was limited to patients with CRC who had an elective surgical resection. Patients who had undergone emergency resections (eg, for bowel obstruction, bleeding or perforation secondary to CRC) or Hartmann's procedures were excluded because these are not routinely considered for laparoscopic resection.

### *Statistical analysis*

Costs are presented in €2012 after inflating Australian dollars to 2012 using the Australian Consumer Price Index (19) and converting to Euro(20) (AUD 1 = € 0.81354).

Hospitals were categorised as 'high volume' if they conducted at least 80 resections for CRC over the two year period of the study. Procedures were grouped according to their relative technical difficulty (see Tables 1 and 2). The intention-to-treat principle was applied throughout the analyses.

The t-test was used to compare the unadjusted mean costs of laparoscopic versus open resection; and multivariate, ordinary-least-squares regression was used to compare the adjusted mean costs after accounting for differences in age, sex, Dukes stage, Charlson Co-morbidity Index (excluding diagnosis codes for CRC and metastatic cancer), hospital volume (high/low) and type of procedure (eg. right hemicolectomy, anterior resection). The robust variance method of Huber and White was used to account for any heteroscedasticity.(21)

Cost data are known to be right-skewed (a few patients have very high costs) .(22) For small sample size, right-skewed data can invalidate statistical inferences based on multivariate, ordinary-least-squares regression. However, for the large sample available for this study, simulation studies have shown that statistical inferences based on multivariate ordinary-least-squares regression are valid.(22) Also, mean costs are preferred by service planners and budget holders.(22) Nevertheless, to confirm the robustness of our conclusions, we also provide adjusted median costs, using absolute residuals regression.(23) Marginal analysis was used to determine the adjusted means from the ordinary-least-squares regression model. All analyses were undertaken using STATA Version 11 statistical software.(24)

Ethical approval was granted by the Queensland Health Human Research Ethics Committee, and, The University of Queensland's, School of Population Health Human Research Ethics Committee.

## RESULTS

Over the two years, 1 391 patients had elective resection for CRC across 18 public hospitals. Eight hospitals were high volume (>80 major resections during the two years) and accounted for 1 031 (74%) of the resections. The mean age of the patients was 67 years; 800/1 397 (57%) were men; and 670/1 391 (48%) had rectal surgery.

Slightly more than half of the patients had a laparoscopic resection (744/1 391; 53%); which was more common among younger patients, with no co-morbidities and those who were treated in high-volume hospitals (Table 1). Laparoscopic resection was more commonly performed for anterior (and high anterior) resections of the rectum (Table 1), reflecting the centralisation of rectal surgery to high-volume hospitals. Open surgery was more common for resections of the sigmoid, transverse and right colon (Table 1).

Of the 1 391 patients, 17 (1.2%) died during the admission for resection (open: 13 deaths; laparoscopic: 4 deaths). Exclusion of deaths made no material difference to the cost results; all cost analyses include deaths.

The unadjusted mean cost was €20 036 for laparoscopic resection and €22 780 for open resection (difference: €2 744). The unadjusted median cost was €17 008 for laparoscopic resection and €18 094 for open resection (difference: €1 086).

Factors influencing total cost, length-of-stay, surgery duration and duration admitted to ICU are shown in Table 2. Older patients, those with co-morbidities, those with metastases and those having rectal surgery incurred greater costs. Patients treated in high-volume hospitals incurred lower costs. Increased costs for the rectal procedures

(abdomino-perineal resection, anterior resection and ultra low anterior resection) coincide with increases in length of stay and surgery duration (Table 2).

After accounting for any differences in age, sex, co-morbidities, stage, type of procedure and hospital volume, the adjusted mean cost for laparoscopic resection was €20 369 versus €22 442 for open resection (difference: €2 053) (Table 3). The adjusted median cost was €808 (95%CI: €33, €1584) less for laparoscopic resection.

Most of the difference in cost (mean or median) was accounted for by shorter length-of-stay and fewer and shorter ICU admissions. Including length-of-stay in the adjusted model decreased the mean difference in cost to €314 (95%CI: -€1215, €587), while including admission to ICU reduced the mean difference in cost to €841 (95%CI: -€2290, €608).

To further check the robustness of the result that laparoscopic surgery is associated with substantially lower costs than open surgery, we conducted an analysis on a homogeneous subgroup, similar to patients recruited to RCTs for laparoscopic surgery (<80 years of age, no metastasis, no pre-planned ICU admission, no chronic pulmonary disease, no pre-existing heart failure). After adjusting for age, sex, stage, co-morbidities, type of surgery, and hospital volume within this subgroup, the results were similar to those for the entire study population. Specifically, the adjusted mean was €18 917 for laparoscopic resection, €20 986 for open resection (difference: €2 068: 95%CI €379, €3 758). Similarly, a separate analysis restricted to high-volume hospitals, found that the difference in adjusted mean cost was €2 107 (95%CI: €458, €3 756).

ICU admission (224 patients) was more frequent for open versus laparoscopic resection (22.6% versus 10.5%,  $P < 0.001$ ). Pre-planned ICU admissions were more common among patients having open resection (70/647; 10.8%) compared with laparoscopic resection (43/744; 5.8%). Patients who had a pre-booked ICU admission were older and more likely to have co-morbidities; these factors, along with procedure type and hospital volume, were included in the multivariate analysis. That is, the analysis adjusts for these differences. To further assess the possible effect of pre-booked ICU admissions, we conducted analyses with these patients excluded: the adjusted mean costs decreased to €19 754 for laparoscopic resection, €21 350 for open resection (difference: €1 595; 95%CI €18, €3 173), and difference in ICU duration decreased to -5.4 hours (from -7.3 hours; Table 2). In short, the results were robust to the effect of pre-planned ICU admissions.

## Discussion

This study, in a region where uptake is mature, found that laparoscopic resection is significantly less expensive than open resection for CRC. This coincides with laparoscopic patients having shorter length of stay, fewer and shorter admissions to ICU, and equivalent operating times compared with open resection.

In 2006, the National Institute of Health and Clinical Excellence (NICE) in the UK, found that laparoscopic surgery for CRC was slightly more expensive (£265) compared with open resection.<sup>(25)</sup> Franks *et al* (2006) reported similar results based on patients recruited into the MRC CLASICC trial (UK) between 1996 and 2002.<sup>(4)</sup>

However, the mean cost (inflated to 2013 from 1999)<sup>(26)</sup> reported by NICE, was about half that found in our study; €10 833 (£9 186) in the laparoscopic group compared with €10 415 (£8 829) in the open group.<sup>(25)</sup> Similarly, Norwood *et al* (2008) who compared costs using a cohort from the ALCCaS RCT, report total costs of admission which are less than half that found in this study.<sup>(7)</sup> As they are based on patients recruited into RCTs, the cost comparisons by NICE and Norwood *et al* (2008), exclude patients with more complex care needs and the associated higher costs.

The ALCCaS RCT reports operating time for laparoscopic resection 60 minutes longer than for open resection, resulting in statistically significant increased costs for operating surgeon, anaesthetist and operating room staff.<sup>(7)</sup> In this current study, there was no difference in the duration of surgery, indicating that the difference in theatre costs was because of utilisation of equipment rather than time dependent resources such as staffing. The ALCCaS RCT reported an increased cost in disposable surgical equipment used in theatre of €215 (\$AUS274) for the laparoscopic

group,(7) which is slightly more than the unadjusted mean increase in theatre cost of €120 found in this current study. This slightly smaller cost associated with disposable surgical equipment is probably, in-part, because the more experienced surgeons treating this cohort of patients have developed efficient techniques including a reduction in the use of staples.

Like all observational (non-randomised) studies, this present study could be subject to confounding. That is, lower cost for laparoscopic versus open surgery could be due to differences in the types of patients, rather than the laparoscopic approach, per se.

Laparoscopic patients were slightly less likely to have some characteristics that tend to increase costs: age older than 75 years, metastases, co-morbidities and treatment in a low-volume hospital. On the other hand, they were more likely to have rectal procedures, which tend to increase cost. The results in this paper are adjusted for these potential confounders. This is also the case for factors which may have contributed to pre-planned admission to ICU (age and co-morbidities). In addition, we defined a more homogeneous subgroup (<80 years of age, no metastasis, no pre-planned ICU admission, no chronic pulmonary disease, no pre-existing heart failure) and still found a difference of about €2 000. Also, a separate analysis confined to high-volume hospitals similarly found that the adjusted mean total cost was about €2 100 lower for laparoscopic than open resection.

In conclusion, the results of this study are different from those of earlier studies, which have reported similar or slightly higher costs for laparoscopic versus open resection for CRC. The lower cost for laparoscopic versus open resection is most likely because Queensland is further along the adoption curve and the majority of surgeons are well-experienced in the procedure. For instance, previous studies have

reported longer operating times for laparoscopic resection,(8) while this study found no difference in operating time, even after adjusting for potential confounders such as procedure type and co-morbidities.

The findings of this study indicate that, in regions where the procedure is widely adopted and surgical teams are experienced in the technique, there will be cost savings associated with laparoscopic resection for colorectal cancer because of fewer admissions to ICU, and decreases in surgery duration and length of stay. Specific inferences regarding the degree of cost benefit in other settings will depend on the relative cost of these determinants. For instance, it may be inferred that healthcare systems where hospital bed days are more expensive than in this study, will see greater cost benefit.

## **Acknowledgments**

While conducting this research, the lead author received salary support from the Patient Safety and Quality Improvement Service, Queensland Health, and a PhD Scholarship from the Australian Centre for Health Services Innovation (AusHSI).

The authors would like to express their gratitude to Colin Roberts, Business Intelligence Officer, Queensland Health, for extracting the data required for this study and for sharing his invaluable knowledge of the data sources.

## **Financial disclosure**

Bridie Thompson and Drs Coory, Gordon and Lumley have no conflicts of interest or financial ties to disclose.

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**Table 1:** Patient characteristics

N = 1391	n (%)		Difference % (95%CI)
	Open N = 647	Laparoscopic N = 744	
<b>Age group</b>			
<65	236 (36.5)	282 (37.9)	1.4 (-3.7, 6.5)
65-74	205 (31.7)	261 (35.1)	3.4 (-1.6, 8.4)
75+	206 (31.8)	201 (27.0)	-4.8 (-9.6, 0.1)
<b>Hospital Volume</b>			
High	455 (70.3)	576 (77.4)	7.1 (2.5, 11.7)
<b>Sex</b>			
Male	370 (57.2)	425 (57.1)	0.1 (-5.3, 5.2)
<b>Dukes stage</b>			
A/B	438 (67.7)	504 (67.7)	0.0 (-4.9, 5.0)
C	133 (20.6)	169 (22.7)	2.2 (-2.2, 6.5)
D	76 (11.8)	71 (9.5)	-2.2 (-5.5, 1.0)
<b>Charlson Index</b>			
0	516 (79.8)	645 (86.7)	6.9 (3.0, 10.9)
1	70 (10.8)	54 (7.3)	-3.6 (-6.6, -0.5)
2+	61 (9.4)	45 (6.1)	-3.2 (-6.1, -0.4)
<b>Procedure group</b>			
<b>Colon</b>			
Right hemicolectomy	205 (31.7)	201 (27.0)	-4.7 (-9.5, 0.1)
Transcolectomy	18 (2.8)	10 (1.3)	-1.4 (-3.0, 0.1)
Extended right hemicolectomy / total colectomy	52 (8.0)	60 (8.1)	0.1 (-2.8, 2.9)
Left hemicolectomy	59 (9.1)	56 (7.5)	-1.6 (-4.5, 1.3)
Sigmoidectomy	52 (8.0)	30 (4.0)	-4.0 (-6.5, -1.5)
High Anterior Resection	42 (6.5)	101 (13.6)	7.1 (4.0, 10.2)
<b>Rectal</b>			
Abdomino-perineal resection	56 (8.7)	47 (6.3)	-2.3 (-5.1, 0.4)
Anterior resection of the rectum	158 (24.4)	233 (31.3)	6.9 (2.2, 11.6)
Ultralow anterior resection	5 (0.8)	6 (0.8)	0.0 (-0.9, 1.0)

**Table 2:** In-hospital resource utilisation surgery access/type, patient characteristics and hospitals volume

	Total cost (€2012) N = 1 273	Length-of-stay (days) N = 1 391	Surgery duration (mins) N = 1 040	ICU duration (hours) N = 1 391
<b>Surgical access</b>	P = 0.010	P = 0.008	P = 0.687	P = 0.002
Open	Reference	Reference	Reference	Reference
Laparoscopic	-2 054 (-3 609, -498)	-1.1 (-1.9, -0.3)	2.6 (-10.2, 15.5)	-7.3 (-11.9, -2.7)
<b>Age group</b>	P = 0.203	P <0.001	P = 0.375	P = 0.909
<65	Reference	Reference	Reference	Reference
65-74	1 467 (-780, 3 715)	1.2 (0.4, 2.1)	-1.1 (-14.2, 12.0)	3.1 (-3.2, 9.5)
75+	1 748 (-647, 4 143)	3.0 (2.0, 4.1)	-0.6 (-16.4, 15.2)	0.6 (-6.0, 7.2)
<b>Sex</b>	P = 0.066	P = 0.022	P = 0.008	P = 0.369
Female	Reference	Reference	Reference	Reference
Male	1 385 (-94, 2 863)	0.9 (0.1, 1.6)	17.4 (4.5, 30.2)	2.0 (-2.4, 6.5)
<b>Dukes Stage</b>	P = 0.180	P = 0.037	P = 0.509	P = 0.984
A/B	Reference	Reference	Reference	Reference
C	-241 (-1 803, 1 321)	0.6 (-0.3, 1.6)	-3.0 (-15.3, 9.4)	-5.2 (-9.2, -1.2)
D	2 513 (-449, 5 475)	1.1 (-0.3, 2.5)	15.8 (-10.1, 41.8)	3.9 (-4.4, 12.3)
<b>Charlson co-morbidity index</b>	P <0.001	P <0.001	P = 0.070	P <0.001
0	Reference	Reference	Reference	Reference
1	5 902 (2 629, 9 175)	2.6 (1.0, 4.2)	6.6 (-16.0, 29.3)	13.3 (1.3, 25.3)
2+	16 404 (9 576, 23 232)	7.4 (4.8, 10.0)	31.8 (-0.9, 64.6)	42.1 (21.6, 62.6)
<b>Procedure type</b>	P <0.001	P <0.001	P <0.001	P = 0.315
Right hemicolectomy	Reference	Reference	Reference	Reference
Transcolectomy	3 788 (-854, 8 429)	-0.2 (-1.8, 1.4)	84.0 (17.0, 151.1)	1.6 (-16.1, 19.3)
Sigmoidectomy	2 001 (-2 214, 6 216)	0.6 (-0.7, 1.8)	35.0 (5.2, 64.9)	2.3 (-11.3, 15.9)
Extended right hemicolectomy/ total colectomy	1 914 (-337, 4 166)	1.5 (0.1, 2.8)	16.5 (-10.2, 43.2)	-4.3 (-10.5, 1.9)
Left hemicolectomy	3 997 (-1 012, 9 007)	0.7 (-0.8, 2.3)	25.6 (7.5, 43.7)	6.3 (-7.6, 20.1)
High anterior resection	2 437 (181, 4 693)	-0.2 (-1.2, 0.7)	44.0 (22.7, 65.2)	2.5 (-5.3, 10.2)
Abdomino-perineal resection	10 543 (7 347, 13 740)	6.8 (5.0, 8.6)	69.9 (43.7, 96.0)	6.6 (-2.4, 15.6)
Anterior resection	6 908 (4 772, 9 043)	3.2 (2.0, 4.4)	76.1 (59.6, 92.6)	1.4 (-5.0, 7.7)
Ultra low anterior resection	5 908 (473, 11 343)	2.5 (-1.4, 6.5)	82.8 (29.5, 136.1)	-9.2 (-20.5, 2.1)
<b>Hospital volume</b>	P = 0.041	P = 0.014	P = 0.112	P <0.001
Low	Reference	Reference	Reference	Reference
High	-2 124 (-4 158, -91)	-1.1 (-1.9, -0.2)	-15.3 (-34.1, 3.6)	-14.0 (-20.6, -7.4)

The association between each variable and the outcome of interest was controlled for all other variables included in this table.

**Table 3:** Adjusted\* cost components (€2012), length-of-stay, duration of surgery and anaesthesia, and admission to ICU

	Mean (95% CI)		Difference (95%CI)	P-value
	Open	Laparoscopic		
<b>Total cost (€2012)</b>	26 207 (24 676, 27 738)	23 921 (22 839, 25 002)	-2 286 (-4 121, -452)	0.015
<b>Anaesthesia cost (€2012)</b>	2 521 (2 383, 2 659)	2 850 (2 731, 2 969)	329 (146, 513)	<0.001
<b>Imaging cost (€2012)</b>	157 (125, 152)	197 (152, 243)	41 (-17, 98)	0.167
<b>Pathology cost (€2012)</b>	956 (898, 1 014)	928 (879, 976)	-28 (-105, 48)	0.468
<b>Pharmacy cost (€2012)</b>	269 (191, 346)	181 (143, 220)	-88 (-179, 4)	0.061
<b>Theatre cost (€2012)</b>	6 527 (6 293, 6 761)	6 612 (6 398, 6 827)	85 (-238, 409)	0.606
<b>Length-of-stay (days)</b>	10.3 (9.7, 11.0)	9.2 (8.7, 9.7)	-1.1 (-1.9, -0.3)	0.008
<b>Surgery duration (mins)</b>	214 (204, 224)	216 (209, 224)	2.6 (-10.2, 15.5)	0.687
<b>Anaesthesia duration (mins)</b>	261 (251, 272)	260 (252, 269)	-0.6 (-14.4, 13.3)	0.937
<b>ICU admission (hours)</b>	14.7 (10.8, 18.7)	7.4 (4.8, 10.0)	-7.3 (-11.9, -2.7)	0.002

\* Adjusted for age, sex, stage, Charlson Co-morbidity Index, type of procedure and hospital-volume