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The Introduction of Laparoscopic Colorectal Surgery: Can It Improve Hospital Economics?

Martijn Maassen van den Brink[a] Thaís T.T. Tweed[a] Patrick A. de Hoogt[b] A.G.M. Hoofwijk[a] Karel W.E. Hulsewé[a] Meindert N. Sosef[a] Jan H.M.B. Stoot[a]

[a]Department of General Surgery, Zuyderland Medical Center, Sittard-Geleen, The Netherlands; [b]Department of Vascular Surgery, Maastricht University Medical Center, Maastricht, The Netherlands

Keywords
Cost analysis · Colorectal cancer · Laparoscopic colorectal surgery

Abstract
Introduction: Clinical benefits of laparoscopic surgery are well established, but evidence for financial benefits is limited. This study aimed to compare the financial impact of the introduction of laparoscopic colorectal surgery. ***Methods:*** This study included patients who underwent colorectal surgery between January 2010 and 2015. We collected a range of financial data and divided the patients into 2 groups. Primary outcome was total cost defined by surgical-related costs. ***Results:*** A total of 1,246 patients were included, of which 440 surgeries were performed laparoscopically. The total median cost of laparoscopy was higher compared to open surgery (EUR 4,665 vs. EUR 4,268, $p = 0.001$). Laparoscopy was associated with higher equipment costs (EUR 857 vs. EUR 232, $p < 0.001$), longer operating time (3.2 vs. 2.5 hours, $p < 0.001$), and more readmissions (10.9 vs. 8.5%, $p < 0.001$). However, after adjusting for heterogeneity, no difference was found in total cost. Surgical-related costs were counterbalanced by lower costs associated with shorter median hospital stay (6 vs. 9 days, $p < 0.001$), less morbidity (37.3 vs. 55.1%, $p < 0.001$), and less mortality (1.8 vs. 5.6%, $p = 0.013$) for laparoscopy. ***Conclusion:*** During the introduction of laparoscopy for colorectal surgery, no significant differences were found in total cost between laparoscopic and open colorectal surgery. However, favorable postoperative outcomes were achieved with laparoscopic surgery.

Introduction

Over the last decennia, one of the major developments in surgical procedures is the introduction of laparoscopic surgery. Since the introduction of laparoscopy, many other improvements have been made and are still being perfected. However, in the present era of rising healthcare cost and the introduction of new, more expensive treatment options, the business intelligence aspect is of increasing importance.

In previous studies, laparoscopic surgery for colorectal pathology showed promising results. With this approach, the reported outcomes showed significantly less intraoperative blood loss, improved postoperative recovery, less

karger@karger.com
www.karger.com/dsu

Karger

Thaís T.T.
Tweed, Department of Surgery, Zuyderland Medical Center
Dr. H. van der Hoffplein 1
NL–6162 BG Sittard-Geleen (The Netherlands)
th.tweed@zuyderland.nl

need for analgesics, early return of intestinal motility, lower overall morbidity, shorter length of hospital stay (LOS), and a higher reported quality of life [1–4]. Moreover, the oncological safety of laparoscopy has been proven, with comparable rates of complete resections, free resection margins, and better survival for selected patient groups [2, 4–6]. Because of its proven oncological and procedural safety, laparoscopy is now for the preferred technique in colorectal surgery. Despite the evidence of improved clinical outcomes, the utilization of laparoscopy is still estimated to be less than 50% of all possible cases [7]. The evidence for the financial advantages of laparoscopy is currently limited and inconsistent. Expected higher costs by the use of more expensive materials and longer operative time, may limit its widespread utilization [8]. However, these costs could be counterbalanced by the benefits of laparoscopy, such as shorter LOS and less postoperative complications [9–12].

From a business intelligence viewpoint, it remains unclear if the introduction of laparoscopic surgery improved healthcare cost. Therefore, we aimed to compare the financial impact of laparoscopic colorectal surgery by investigating the overall surgical-related costs.

Materials and Methods

Study Design

This study is a single-center retrospective cohort analysis from the Zuyderland Medical Center (ZMC). Patients who electively underwent either laparoscopic or open colorectal resection between January 2010 and 2015 were included in this study based on an intention-to-treat analysis. To identify these patients, the prospective financial control file system was searched for all procedure codes for colorectal surgery. Patients with additional resections during the operation were excluded. The primary outcome was total cost defined by surgical-related costs. Surgical-related costs included costs of hospitalization, occupation of the operating theater, equipment costs, readmission, and surgical reintervention costs. Secondary outcomes were LOS and LOS-associated costs, postoperative complications, readmission, and mortality within 30 days. Due to its retrospective design and period of data collection, written informed consent was not required. This study was approved by the ZMC's committee on human research (METC-Z, 15-N-105).

Data

All demographical, surgical, and perioperative outcome data of these patients were collected in a prospectively coded database. Data were obtained from the electronic patient files and verified with the Dutch Institute for Clinical Auditing database. Operations were performed by both surgeons and (supervised) surgical residents. The choice for laparoscopic or open colorectal surgery was based on the preference of the patient and surgeon. If both options were possible, the choice depended on the patient's preference. All patients received usual care following enhanced recovery after surgery (ERAS) protocol [13]. The cost of inventory-apparatus (insufflator, video-camera, monitors, etc.) was not included, just as other non-surgical-, outpatient-, and community costs.

All costs were obtained from the financial office and are reported in euros (€). Hospitalization costs were based on the LOS from hospital admission to discharge. The costs of the operating theater were based on the time of occupation. Costs of disposable and nondisposable equipment were based on the preoperative standard equipment list and were also calculated from the actual costs paid by the hospital.

Statistical Analysis

All data were analyzed based on an intention-to-treat analysis. Categorical data variables are expressed as numbers with percentages and were analyzed with the χ^2 test. For parametric continuous data, the Student's *t* test was used and data presented as mean with standard deviation. For nonparametric continuous data, the Mann-Whitney U test was used and presented as median with interquartile ranges. Linear logistic regression analysis was used to examine factors influencing total surgical-related cost. For the multivariate analysis, multiple linear regressions including all variables were performed. Logistic regression was used to calculate the adjusted odds ratio. A two-tailed p value ≤0.05 was considered as statistically significant. Performed statistical analyses were in consultation with an epidemiologist and a statistician and using the IBM SPSS statistics software program, version 25.0.

Results

Patient Characteristics

Within the study period, a total of 1,246 patients were operated in our institute. Ninety-one patients with additional resections were excluded. The remaining 1,155 patients were divided according to surgical procedure. A total of 440 patients underwent laparoscopic surgery and 715 patients underwent open surgery. The 2 groups differed in age, the American Society of Anesthesiologists (ASA) classification, operation indication, and tumor stage. The most common indications for colorectal surgery were malignancy (63%), diverticulitis (14%), and inflammatory bowel disease (IBD) (9%). Of all resections, 75% were resections of the colon (Table 1).

Primary Outcome

Both the mean and median total cost of laparoscopic surgery were higher than the total cost of open surgery. In the open group, there was a wide distribution of total cost, which prompted a more accurate display of these data by using the median values. Despite patients in the laparoscopy group having a shorter LOS and fewer surgical reinterventions, the median total cost was higher when compared to that of the open group (EUR 4,665 vs. EUR 4,268, $p < 0.001$). This was mainly due to signifi-

Table 1. Summary of patient characteristics at the baseline and comparison between the groups

Variable	Laparoscopy (%) N = 440	Open (%) N = 715	p value
Demography			
Age	64.33 (SD 13.89)	68.34 (SD 13.06)	<0.001
Male	227 (52.0)	364 (51.0)	0.822
Health			
BMI, kg/m^2	26.63 (SD 4.69)	26.21 (SD 4.60)	0.145
Mean	87 (19.8)	141 (19.7)	0.983
Obesity, BMI > 30	393 (89.3)	538 (75.2)	<0.001
ASA classification	47 (10.7)	177 (24.8)	
1 and 2			
3 and 4			
Diagnosis			
Malignancy	241 (54.8)	482 (67.4)	<0.001
Diverticulitis	74 (16.8)	82 (11.5)	
IBD	58 (13.2)	46 (6.4)	
Benign polyp	39 (8.9)	37 (5.2)	
Other*	28 (6.4)	68 (9.5)	
TNM classification			
Stadium 0	20 (8.3)	21 (4.4)	0.096
Stadium 1	56 (23.2)	96 (19.9)	
Stadium 2	67 (27.8)	151 (31.3)	
Stadium 3	82 (34.0)	161 (33.4)	
Stadium 4	16 (6.6)	53 (11.0)	
Comorbidities			
Cardiac	103 (23.4)	180 (25.2)	0.498
Pulmonary	58 (13.2)	82 (11.5)	0.386
History of abdominal surgery	146 (33.2)	223 (31.2)	0.481
Diabetic types 1 and 2	43 (9.8)	125 (17.5)	<0.001
Hypertension	148 (33.6)	220 (30.8)	0.310
Resection			
Colon resection	326 (74.1)	540 (75.5)	0.624
Conversion	43 (9.8)		

Unless otherwise indicated, values represent the total number and percentages. ASA, America Society of Anesthesiologists; IBD, inflammatory bowel diseases (ulcerative colitis and Morbus Crohn); TNM, classification of malignant tumors, seventh edition, 2009. * Other group of rare operation indications (perforation, ischemia, ileus, slow-transit colon, and volvulus).

cantly higher costs for more expensive equipment and higher operating theater costs (EUR 857 vs. EUR 232 and EUR 2,573 vs. EUR 2,035, respectively). After having adjusted for the differences in the baseline characteristics, the median total cost did not differ between groups (p = 0.391) (Table 2).

Secondary Outcomes

Patients in the laparoscopic group had a significantly shorter LOS compared to patients in the open group, 6 versus 9 days (Table 3). Patients in the laparoscopic group had significantly lower median costs of hospitalization (EUR 1,037 vs. EUR 1,560) and readmission costs (EUR 900 vs. EUR 1,980). This was mainly attributed by a shorter LOS and less intensive care unit (ICU) admissions in the laparoscopy group (see online suppl. Fig. 1; see www.karger.com/doi/10.1159/000511180 for all online suppl. material). Even after adjustment for baseline characteristics, these outcomes remained significant (Table 2).

Table 2. Comparisons of the number and costs between open and laparoscopic surgery

Variable		Number of patients (laparoscopy/Open)	Laparoscopy, IQR	Open, IQR	*p* value	Adjusted *p* value*
Operation theater		436**/714**	2,573 (2,029–3,267)	2,035 (1,596–2,635)	<0.001	<0.001
Equipment costs		440/715	857 (SD = 79)	232 (SD = 28)	<0.001	<0.001
Hospitalization	Ward	440/715	1,033 (711–1,598)	1,417 (923–2,337)	<0.001	<0.001
	ICU	47/193	690 (304–3,386)	733 (322–1,673)	0.817	0.565
	Total	440/715	1,037 (712–1,612)	1,560 (1,053–2,661)	<0.001	<0.001
Readmission		47/61	900 (540–2,070)	1,980 (1,260–3,060)	<0.001	0.007
Surgical reintervention		43/104	2,172 (1,650–2,435)	1,468 (1,052–2,190)	0.001	0.067
Total cost	Mean	436**/714**	5,630 (SD = 3,120)	5,462 (SD = 4,062)	<0.001	
	Median		4,665 (3,923–6,204)	4,268 (3,215–6,176)	<0.001	0.391

All costs are represented in the € and as median with IQRs or mean with SD. ICU, intensive care unit; IQR, interquartile range; SD, standard deviation; €, European currency. * Adjusted *p* value for baseline characteristics (age, gender, BMI, ASA, pathology, and cancer stadium). ** Missing data excluded from analysis.

Table 3. Comparisons of the perioperative outcomes between open and laparoscopic surgery

Variable	Laparoscopy, %	Open, %	*p* value	Adjusted *p* value
LOS	440 (100.0)	715 (100.0)	<0.001	<0.001
Days, *N* =	6.0 (4.0–10.5)	8.8 (5.9–15.1)		
Ward	440 (100.0)	715 (100.0)	<0.001	<0.001
Days	5.7 (4.0–8.9)	7.9 (5.1–13.0)	<0.001	0.565
ICU admission	47 (10.7)	193 (27.0)	0.817	
Days	1.6 (0.7–8.0)	1.7 (0.8–3.9)		
Occupation time OT*	436 (99.1)	714 (99.9)	<0.001	<0.001
Hours	3.2 (2.5–4.1)	2.5 (2.0–3.3)		
Readmission*	47 (10.9)	61 (8.5)	0.223	0.007
Days	5.0 (3.0–11.5)	11.0 (7.0–17.0)	<0.001	
Surgical reintervention*	43 (9.8)	106 (14.8)	0.013	0.892
Hours	1.8 (1.3–2.4)	1.5 (1.0–2.4)	0.551	
Total complications**	*N* = 164 (37.3)	*N* = 386 (55.1)	<0.001	
1. Ileus	37 (8.4)	110 (15.4)	0.001	
2. Wound infection	28 (6.4)	73 (10.2)	0.025	
3. Anastomotic leakage	29 (6.6)	60 (8.4)	0.265	
4. Abscess	27 (6.1)	53 (7.4)	0.407	
5. Urinary infection	21 (4.8)	58 (8.1)	0.029	
6. Pneumonia	16 (3.6)	56 (7.8)	0.004	
7. AKI	18 (4.1)	54 (7.6)	0.018	
8. Sepsis	11 (2.5)	33 (4.6)	0.068	
9. Delirium	5 (1.1)	37 (5.2)	<0.001	
10. Ischemia	9 (2.0)	30 (4.2)	0.049	
11. Wound dehiscence	7 (1.6)	33 (4.6)	0.025	
30-day mortality	8 (1.8)	40 (5.6)	0.002	

All data are presented in number and percentages or in median with interquartile ranges. IQR, interquartile ranges; ICU, intensive care unit; OT, operating theater; AKI, acute kidney injury; LOS, length of hospital stay. * Adjusted *p* value for baseline characteristics (age, gender, BMI, ASA, pathology, and cancer stadium). ** Multiple complications per patient included.

Table 4. Adjusted odds ratio for quality measures between laparoscopic and open surgery

Factors		Cases, %	AOR	95% CI	*p* value
Readmission rate	Open Laparoscopy	61 (8.5) 47 (10.9)	1 1.269	Reference 0.834–1.934	0.266
Surgical reintervention rate	Open Laparoscopy	106 (14.8) 43 (9.8)	1 0.590	Reference 0.398–0.876	0.009
Complication rate	Open Laparoscopy	386 (55.1) 164 (37.3)	1 0.530	Reference 0.409–0.687	<0.001
30-day mortality rate	Open Laparoscopy	40 (5.6) 8 (1.8)	1 0.518	Reference 0.222–1.208	0.128

Adjusted for baseline characteristics (age, gender, BMI, ASA, pathology, and cancer stadium). CI, confidence interval; AOR, adjusted odds ratio; B, indicates the unstandardized regression coefficient.

Table 5. Uni- and multivariate regression analysis of factors contributing to the total cost

Factors	Univariate B	β	*p* value	Multivariate B	β	*p* value
Age	−1.904	−0.007	0.815			
Gender	605.43	0.081	0.006	178.30	0.024	0.369
BMI Obesity	2.37 278.40	0.003 0.030	0.922 0.314			
ASA classification*	771.44	0.110	<0.001	294.76	0.042	0.122
Diagnosis (malign/benign)	−641.99	−0.083	0.005	−810.62	−0.102	<0.001
Side of resection (colon/rectum)	−1,669.74	−0.194	<0.001	−1,454.63	<0.169	<0.001
Cancer stadium (0, 1 and 2/3 and 4)	−191.16	−0.032	−0.389			
Surgical approach (laparoscopy/open)	−167.47	−0.022	0.461			
Conversion Complication (yes/no)	951.18 3,190.37	0.090 0.427	0.060 <0.001	2,948.38	0.395	<0.001

B indicates the unstandardized regression coefficient in the European currency (€); β standardized regression coefficient. ASA, American Society of Anesthesiologists. * ASA, per advanced level.

Moreover, the laparoscopic group had significantly fewer ICU admissions (11 vs. 27%), surgical reinterventions (10 vs. 15%), patients with complications (37 vs. 55%), and 30-day mortality (1.8 vs. 5.6%). But the laparoscopic group had a significantly longer operating time (3.2 vs. 2.5 h) (Table 3).

After having adjusted for the baseline characteristics, patients in the laparoscopic group remained 48% less likely to die between operation and postoperative day 30. This likeliness was, however, not significant ($p = 0.128$). These patients were also 47% less likely to have a complication ($p < 0.001$) and 41% less likely to have a surgical reintervention ($p = 0.009$) (Table 4).

Cost-Affecting Factors

Univariate and multivariate logistic linear regression analyses were performed to identify factors that contributed to the total cost of colorectal surgery. The multivariate analyses included all significant factors derived from the univariate analyses. These analyses showed a significant association in total cost increase for 3 factors: having a benign diagnosis, a rectum resection, or postoperative complication (Table 5).

Discussion/Conclusion

The purpose of this study was to evaluate the financial aspects of the introduction of laparoscopic colorectal surgery. This study found comparable total cost between laparoscopic and open colorectal surgery, only after adjusting for confounding factors. Reduced LOS and better postoperative outcomes compensated for higher equipment costs and longer operating time of laparoscopic surgery. These findings show that the introduction of laparoscopic surgery may have little economic advantages for the hospital, but it remains beneficial for patients' postoperative outcomes with reduced overall complications and mortality.

Previous studies comparing the total cost of surgical procedures were not done uniformly, considering that each study uses different methods for calculating the individual costs. This study only focused on the cost directly associated with surgical procedures, to investigate its effect on hospital budget. This study did not include imaging costs, prescribed medication costs, outpatient costs, or community costs. Despite not having included these, similar values to previous studies were observed [10–12, 14–17]. Early laparoscopy cost-effectiveness studies, reported varying results comparing the cost of laparoscopic to open colorectal surgery [15, 17]. Dowson et al. [16] reported an overall 50% (IQR 27–78%, $p < 0.001$) higher operating room costs for laparoscopic surgery but no overall difference in total hospital cost. This was acquitted to a shorter median LOS of 2.8 days (IQR 1.3–3.7, $p < 0.001$). Higher operating room costs were due to more expensive equipment and longer operation duration due to the learning curve of the new laparoscopic approach [16]. In more recent studies, cost-benefits for laparoscopic surgery were realized with shorter LOS and better postoperative outcomes [10–12, 14]. Keller et al. [12] reported a reduction of 22% in hospital costs in favor of laparoscopic surgery (OR 0.78, C.I. 0.751–0.848) with a reduction of 2 days in LOS and reduced costs for laparoscopic surgery.

In this study, the effect of the learning curve and more expensive equipment is probably the main contributing factors to higher cost for laparoscopic surgery. Nowadays, surgical cost-effectiveness may be further improved by reducing operating time and the use of reusable instruments. Recently, Yi et al. [18] evaluated the impact of the surgeon's experience on the total cost of laparoscopic surgery. Surgeons in high-volume centers experience shorter operating times, lower hospitalization costs, and shorter LOS. They suggest that these benefits may outweigh the learning curve-associated costs tied to the skill acquisition of laparoscopic surgery [18]. Other studies have shown that the number of perioperative-related complications, morbidity, and mortality rates decreased with increasing experience of the surgeon performing laparoscopic surgery [19, 20].

Currently, almost all colorectal procedures in this hospital are performed laparoscopically. Now, a further decline in operating times is being recorded for colorectal surgery in this hospital, assuming that the learning curve has been achieved (online suppl. Fig. 2). Keller et al. [12] recently reported significantly shorter LOS, lower readmission rates, morbidity, and mortality rates for laparoscopic colorectal surgery. In the present study, comparable reductions were found in LOS, complication, and mortality rates (Table 4). Currently, further reductions in LOS are achieved by optimizing ERAS programs, improving the laparoscopic experience and surgical skills. Also, to increase the cost-effectiveness of laparoscopic surgery, reusable instrument should be implemented for routine use [21, 22].

Like previous studies, this study found several independent factors such as having a benign pathology and resection of the rectum, to affect the total cost of colorectal surgery [11, 23, 24]. Higher costs due to a benign pathology may in part be linked to the inflammatory pathophysiology of IBD. Compared to malignancy, the postoperative risk for abscesses or reinterventions is higher for patients with IBD.

This study has a few limitations. Although all data were recorded in a prospective electronic database system, we encountered some missing data due to its retrospective design. The results may, therefore, lack external validity. However, it represents data of common practice in a teaching hospital with a high number of patients during a 5-year period. Also, our groups were not homogeneous; hence, we adjusted for confounding factors. Heterogeneity between our groups might be explained by the fact that upon introduction, laparoscopic surgery would be applied at first in relatively younger (IBD) patients, and the open approach was preferred for higher TNM-stadia of colorectal cancer patients. Last, the learning curve concept may have played a role in the overall surgical time, as laparoscopic surgery was introduced in 2009 in our hospital.

In this study, the cost of the introduction of laparoscopic colorectal surgery was investigated over a 5-year period in more than 1,200 patients. Both the mean and median total cost of laparoscopy were higher than that of open surgery, 3 and 8%, respectively. However, after adjusting for heterogeneity, no differences were found in total cost.

Additionally, shorter LOS, less ICU admission, and reduced morbidity and mortality were found for laparoscopy. Overall preference for laparoscopic colorectal surgery can be achieved by further reducing operating time and equipment costs.

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Statement of Ethics

This research complied with the guidelines for human studies and was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. Due to the retrospective design of this study and period of data collection, written informed consent collection was not required as approval for this study was obtained before the implementation of the General Data Protection Regulation (GDPR). This study was approved by the ZMC's committee on human research (METC-Z, 15-N-105).

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

M. Maassen van den Brink: acquisition, analysis, interpretation of data, drafting, and critical revision for final approval. T.T.T. Tweed: drafting of work, analysis, interpretation of data, and critical revision for final approval. P.A. de Hoogt: conception, design, analysis, and critical revision for final approval. A.G.M. Hoofwijk: analysis, interpretation of data, and critical revision for final approval. K.W.E. Hulsewé: conception, design, and critical revision for final approval. M.N. Sosef: interpretation of data and critical revision for final approval. J.H.M.B. Stoot: conception, design, analysis, interpretation of data, and critical revision for final approval.

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