Value-based healthcare in colorectal cancer surgery : improving quality and reducing costs

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CHAPTER 5

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MULTICENTER STRATIFIED COMPARISON OF HOSPITAL COSTS BETWEEN LAPAROSCOPIC AND OPEN COLORECTAL CANCER RESECTIONS; INFLUENCE OF TUMOR LOCATION AND OPERATIVE RISK

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ABSTRACT

Objective

To compare actual 90-day hospital costs between elective open and laparoscopic colon and rectal cancer resection in a daily practice multicenter setting, stratified for operative risk.

Summary background data

Laparoscopic resection has developed as a commonly accepted surgical procedure for colorectal cancer. There are conflicting data on the influence of laparoscopy on hospital costs, without separate analyses based on operative risk.

Methods

Retrospective analyses using a population-based database (Dutch Surgical Colorectal Audit). All elective resections for a T1-3N0-2M0 stage colorectal cancer were included between 2010 and 2012 in 29 Dutch hospitals. Operative risk-was stratified for age (75 < years/ ≥ 75 years) and ASA status (I-II/III-IV). Ninety-day hospital costs were measured uniformly in all hospitals based on time-driven activity-based costing.

Results

Total 90-day hospital costs ranged from €10474 to €20865 in the predefined subgroups. For colon cancer surgery (N = 4202), laparoscopic resection was less expensive than open resection in all subgroups, savings because of to laparoscopy ranged from €409 (<75 years ASA I-II) to €1932 (≥ 75years ASA I-II). In patients ≥75 years and ASA I-II, laparoscopic resection was associated with 46% less mortality ($p = 0.05$), 41% less severe complications ($p < 0.001$), 25% less hospital stay ($p = 0.013$), and 65% less ICU stay ($p < 0.001$). For rectal cancer surgery (N = 2328), all laparoscopic subgroups had significantly higher total hospital costs, ranging from €501 (<75 years ASA I-II) to €2515 (≥75 years ASA III-IV).

Conclusions

Laparoscopic resection resulted in the largest cost reduction in patients over 75 years with ASA I-II undergoing colonic resection, and the largest cost increase in patients over 75 years with ASA III-IV undergoing rectal resection as compared with an open approach.

INTRODUCTION

During the past two decades, laparoscopic resection has developed as a commonly accepted surgical procedure for colorectal cancer, although two recent randomized controlled trials (RCTs) question its routine use for rectal cancer. [1,2]. Laparoscopy for colorectal cancer is associated with faster postoperative recovery, similar long-term oncological outcome and similar or better long-term surgical outcome (risk of adhesion related small bowel obstruction and incisional hernia) as compared with open resection [3-6]. However, there have been questions regarding the cost efficacy, mostly because of prolonged operative time and higher costs of operative materials (e.g. disposables) [7,8].

Most studies analyzing financial outcomes after open and laparoscopic resection were based on RCTs [9-11]. Although RCTs are the cornerstone of clinical research, their limitations should be acknowledged, especially regarding external validity [12]. This is related to selection of centers, specialists and patients that participate in these trials. Therefore there is an increasing demand for population-based studies as they may provide important clinical data from patients often not eligible for RCTs [13].

Population-based studies analyzing actual hospital costs after laparoscopic and open colorectal cancer resections are scarce. One of the problems is a lack of uniformity and transparency in registration between different institutions. Another challenge when using population-based data is dealing with nonrandomized comparisons. Differences in patient characteristics can be taken into account by performing multivariate analysis, though this will not correct for unknown factors, which may influence the decision to perform open or laparoscopic surgery. As recently published, the use of risk-stratified comparison between homogenous subgroups based on known operative risk factors is an inventive way to minimize the inherent risk of selection bias in population studies [14]. This also provides better insight in clinically relevant subgroups. Regarding costs, this may be of interest for healthcare providers and/or payers by identifying subgroups of colorectal cancer patients' that financially benefit most from either an open or a laparoscopic approach.

Therefore, the purpose of this population-based analysis was to compare actual 90-day hospital costs between elective laparoscopic and open resection of localized

nonmetastatic colorectal cancer in clinically relevant subgroups based on tumor location and operative risk.

METHODS

Data collection

Data used for this multi-center study (n = 29) was retrieved from a combined clinical and financial dataset of the Dutch Value Based Healthcare Study. A detailed description of this combined dataset has been published recently [15]. Briefly, the clinical data set was retrieved from the Dutch Surgical Colorectal Audit (DSCA), a population-based database in which detailed patient, tumor, diagnostic, procedural and outcome data are registered of all patients undergoing a resection of a primary colorectal carcinoma in the Netherlands [16,17]. The economic evaluation was conducted from a hospital perspective. As such, only in-hospital costs were considered. Costs were taken into account from the day of initial surgery till discharge (primary admission) and first 90 days after discharge (Q1). For each hospital, translation of patient level resource utilization (extracted from the Hospital Information System) into costs was provided by Performation (Bilthoven, the Netherlands), a healthcare consultancy firm providing patient level costing and benchmarking services for more than 100 hospitals across Europe [18]. Costs were calculated using time driven activity-based costing (TD-ABC) methodology [19] which is a bottom-up microcosting method that consists of calculating two parameters per activity: the costs per time unit to perform each activity and the overall time units spent performing the activity. Compared with top-down costing methods, the TD-ABC is superior in terms of revealing patient-level resource-use variations and the prevention of cross-subsidizations [20,21]. Cost price calculations were standardized by Performation and therefore uniformity in methodology exists between all participating hospitals. The most recent cost price model of 2012 for each hospital was used for all years (2010, 2011, and 2012) to avoid differences due to inflation or to the different models themselves. Different activities are grouped into four categories as shown in Supplemental Figure 1. Specialists' fees, medication

costs, and costs for dialyses were excluded since registration of these parameters was not uniform in the participating hospitals making equal comparison impossible.

Inclusion criteria

A detailed description about the inclusion of hospitals and patients in this dataset has been described recently [15]. Because the surgical approach is significantly influenced by the acute setting, locally advanced disease and metastatic disease [6], patients operated in an emergency / urgent setting, with a T4 or unknown T stage, and with M1 stage were excluded. Furthermore, transanal resection and multiple synchronous tumors were excluded. This resulted in a total of 3383 patients who were excluded from the present analysis. Homogenous subgroups within the included patients were defined for further analysis based on tumor location (colon vs rectum), ASA score (I-II vs III-IV) and age (<75 vs ≥ 75 years). For age, a cut-off of 75 year was chosen since literature suggests it might be of clinical importance and many nationwide colorectal cancer screening programs use 75 years as a cut-off as well [22,23].

Definitions

Laparoscopic resection was defined as any procedure started with the intention to resect the tumor using laparoscopic techniques (including converted resections). Converted laparoscopic resection was defined as a procedure that was started with the intention to perform a laparoscopic resection but was completed as an open resection. Between 2010 and 2012, no robotic surgery was performed for colorectal cancer in the participating hospitals.

Primary financial measure was total hospital costs (all hospital costs of primary admission up to 90 days after discharge and therefore including costs of readmission and reoperations). Secondary financial outcomes were costs of primary operation, costs of ICU stay, costs of ward stay and other costs (radiology, materials, consulting, laboratory, and costs of reoperations).

Primary clinical outcome measures were postoperative mortality, defined as inhospital or 30-day mortality and major morbidity, defined as an inhospital or 30-day adverse outcome with

serious consequences leading to mortality, a reintervention (percutaneous or operative), or a postoperative primary hospital stay of at least 14 days. Secondary outcome measures were operation time, length of hospital stay (LOS), and length of ICU stay (ICU LOS).

Analysis

Chi-square test and t-test were used to investigate differences between patients' characteristics in the two different groups (Table 1). Clinical and financial outcomes were presented unadjusted. Odds ratio (OR) with 95% confidence interval (CI) was calculated for each clinical binary outcome. For the financial outcomes, hospital stay and operation time, the normality assumption was violated and therefore a nonparametric test has been used to evaluate the difference between groups [24]. Statistical analyses were performed by using SPSS (version 20.0, IBM SPSS Statistics for Windows, IBM Corp., Armonk, NY) and R (version 18, R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org) [25].

RESULTS

A total of 6530 T1-3N0-2M0 patients were included for analysis. In 4202 patients (64%) the tumor was located in the colon and in 2328 patients (36%) the tumor was located in the rectum. A total of 4126 patients (63%) were aged <75 year versus 2404 patients (37%) aged ≥75 year, 5053 patients (77%) were ASA I-II versus 1477 patients (23%) ASA III-IV. All analyzed patient, tumor and procedure characteristics of the studied population are shown in Table 1.

Colon cancer

For colon cancer, 1827 (43.5%) patients underwent an open resection and 2375 (56.5%) patients underwent a laparoscopic resection (Table 1). The largest subgroup was <75 years ASA I-II (786 open vs 1286 laparoscopic procedures) and the smallest subgroup was <75 years ASA III-IV (153 open vs 205 laparoscopic procedures) (Table 2).

Table 1. Patient, tumor and treatment characteristic of patients included for analysis, stratified by surgical approach

		Colon Cancer					Rectal Cancer				
		Open		Laparoscopy			Open		Laparoscopy		
		n	%	n	%	p-value	n	%	n	%	p-value
Total		1827	43.5%	2375	56.5%		1113	47.8%	1215	52.2%	
Sex	Male	924	50.6%	1320	55.6%	<0.001	703	63.2%	736	60.6%	0.20
Age		72.5		70.3		<0.001	67.7		67.0		0.15
BMI		26.4		26.3		0.18	26.5		26.1		0.01
Charlson score	Charlson 0	826	45%	1308	55.1%	<0.001	623	56%	751	61.8%	<0.001
	Charlson 1	427	23.4%	536	22.6%		242	21.7%	271	22.3%	
	Charlson 2+	574	31.4%	531	22.4%		248	22.3%	193	15.9%	
ASA score	I-II	1282	70.2%	1838	77.4%	<0.001	893	80.2%	1040	85.6%	0.001
	III+IV	545	29.8%	537	22.6%		220	19.8%	175	14.4%	
Tumor location	Right colon	989	54.1%	988	41.6%	<0.001	n/a		n/a		
	Tansv./ left colon	326	17.8%	274	11.5%		n/a		n/a		
	Sigmoid	512	28.0%	1113	46.9%		n/a		n/a		
	Rectum	n/a		n/a			1113	100.0%	1215	100.0%	
Tumor -anal distance	≤5cm	n/a		n/a			418	40.7%	384	33.4%	<0.001
	6-10cm	n/a		n/a			437	42.6%	467	40.6%	
	>10cm	n/a		n/a			172	16.7%	298	25.9%	
Tumor stage (TNM)	Stadium 0	2	0.1%	4	0.2%	<0.001	78	7.0%	63	5.1%	0.24
	Stadium 1	155	8.5%	215	9.1%		85	7.6%	107	8.8%	
	Stadium 2	356	19.5%	604	25.4%		415	37.3%	462	38.0%	
	Stadium 3	1314	71.9%	1552	65.3%		535	48.1%	583	48.0%	

Table 1. Patient, tumor and treatment characteristic of patients included for analysis, stratified by surgical approach (continued)

		Colon Cancer					Rectal Cancer				
		Open		Laparoscopy			Open		Laparoscopy		
		n	%	n	%	p-value	n	%	n	%	p-value
Anastomosis or stoma	Anastomose	1651	90.4%	2147	90.4%	0.06	172	15.5%	251	20.7%	<0.001
	Anastomose & stoma	49	2.7%	90	3.8%		349	31.4%	462	38.0%	
	Stoma	85	4.7%	90	3.8%		567	50.9%	451	37.1%	
	Unknown	42	2.3%	48	2.0%		25	2.2%	51	4.2%	
Conversion		n/a		283	11.9%	n/a	n/a		141	11.6%	n/a
Preoperative -	None	n/a		n/a			158	14.2%	148	12.2%	<0.001
radiotherapy	5 x 5 Gy	n/a		n/a			518	46.5%	684	56.3%	
	28x1.8Gy/ 25x2.0Gy/else	n/a		n/a			437	39.3%	383	31.5%	

Abbreviations: BMI, Body Mass Index; ASA, American Society of Anaesthesiologists risk score; TNM, Classification of Malignant; Gy, gray. Statistical analyses performed using Chi-square test or one-way Anova.

Table 2. Clinical and financial outcomes after open and laparoscopic colon cancer procedures stratified by subgroup

Sub group	Outcome of interest	Open	Laparoscopy	Delta	RD	OR	(95% CI)	P-value
<75Y ASA I-II	n	786	1286					
	Mortality (%)	5 (0.6%)	7 (0.5%)	-0.10%	-16.7%	0.855	(0.27 , 2.70)	0.79
	Severe complication (%)	126 (16.0%)	167 (13.0%)	-3.0%	-18.8%	0.782	(0.61 , 1.00)	0.05
	Conversion rate	n/a	153 (11.9%)					
	Hospital costs	€11214	€10805	-€409	-3.6%	n/a	(€-422 , €-397)	<0.001
	- OR costs (primary OR)	€2458	€3508	€1050	42.7%			
	- ICU costs	€2011	€1737	-€274	-13.6%			
	- Ward costs	€4340	€3687	-€653	-15.0%			
	- Other costs	€2405	€1873	-€532	-22.1%			
	LOS	9.3	8.2	-1.2	-12.7%	n/a	(-1.28 , -1.09)	<0.001
	- LOS ICU	1.0	0.8	-0.2	-19.2%	n/a	(-0.30 , -0.11)	<0.001
	Primary OR time (min)	151	178	27	17.9%	n/a	(0.36 , 0.54)	<0.001
<75Y ASA III-IV	n	153	205					
	Mortality (%)	6 (3.9%)	6 (2.9%)	-1.0%	-25.6%	0.739	(0.23 , 2.34)	0.61
	Severe complication (%)	40 (26.1%)	38 (18.5%)	-7.6%	-29.1%	0.643	(0.39 , 1.06)	0.09
	Conversion rate	n/a	26 (12.7%)					
	Hospital costs	€15199	€14304	-€895	-5.9%		(€-960 , €-829)	<0.001
	- OR costs (primary OR)	€2483	€3695	€1212	48.8%			
	- ICU costs	€4135	€3931	-€204	-4.9%			
	- Ward costs	€5105	€4164	-€941	-18.4%			
	- Other costs	€3475	€2513	-€962	-27.7%			
	LOS	12.5	9.9	-2.6	-20.8%	n/a	(-2.89 , -2.32)	<0.001
	- LOS ICU	2.4	1.9	-0.5	-19.6%	n/a	(-0.67 , -0.25)	<0.001
	Primary OR time (min)	152	183	31	20.5%	n/a	(0.30 , 0.73)	0.02

Table 2. Clinical and financial outcomes after open and laparoscopic colon cancer procedures stratified by subgroup (continued)

Sub group	Outcome of interest	Open	Laparoscopy	Delta	RD	OR	(95% CI)	P-value
≥75Y ASA I-II	n	496	552					
	Mortality (%)	25 (5.0%)	15 (2.7%)	-2.3%	-46.0%	0.526	(0.27 , 1.01)	0.05
	Severe complication (%)	117 (23.6%)	77 (13.9%)	-9.7%	-41.1%	0.525	(0.38 , 0.72)	<0.001
	Conversion rate	n/a	56 (10.1%)					
	Hospital costs	€12406	€10474	-€1932	-15.6%		(€-2016 , €-1850)	<0.001
	- OR costs (primary OR)	€2374	€3403	€1029	43.3%			
	- ICU costs	€3150	€1369	-€1781	-56.5%			
	- Ward costs	€4583	€3959	-€624	-13.6%			
	- Other costs	€2300	€1743	-€557	-24.2%			
	LOS	11.7	8.7	-2.9	-25.2%	n/a	(-3.12 , -2.77)	<0.001
	- LOS ICU	1.6	0.6	-1.0	-64.5%	n/a	(-1.13 , -0.87)	<0.001
	Primary OR time (min)	144	174	30	20.7%	n/a	(0.40 , 0.64)	0.01
≥75Y ASA III-IV	n	392	332					
	Mortality (%)	39 (9.9%)	28 (8.4)%	-1.5%	-15.2%	0.834	(0.50 , 1.39)	0.48
	Severe complication (%)	123 (31.4%)	77 (23.2%)	-8.2%	-26.1%	0.660	(0.47 , 0.92)	0.01
	Conversion rate	n/a	48 (14.5%)					
	Hospital costs	€15047	€14438	-€609	-4.0%		(€-640 , €-578)	<0.001
	- OR costs (primary OR)	€2431	€3556	€1125	46.3%			
	- ICU costs	€4698	€3851	-€847	-18.0%			
	- Ward costs	€5077	€4503	-€574	-11.3%			
	- Other costs	€2841	€2528	-€313	-11.0%			
	LOS	13.6	10.5	-3.1	-22.8%	n/a	(-3.32 , -2.88)	<0.001
	- LOS ICU	2.5	2.1	-0.4	-16.7%	n/a	(-0.57 , -0.27)	<0.001
	Primary OR time (min)	145	181	36	24.7%	n/a	(0.44 , 0.76)	<0.001

Abbreviations: AD, absolute difference; RD, relative difference; OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists classification.

Subgroup <75 years ASA I-II open was used as a reference group (Figure 1A). Subgroups <75 years ASA I-II laparoscopic and ≥75 years ASA I-II laparoscopic were significant less expensive as compared with the reference group (95% CI €-4212, -€397 and €-713, €-769, respectively). Care provided to patients in each of the remaining subgroups was more expensive than that of the reference group: <75 years ASA III-IV open (95%CI €3804, €4165), <75 years ASA III-IV laparoscopic (95%CI €2954, €3226), ≥75 years ASA I-II open (95%CI €1146, €1238), ≥75 years ASA III-IV open (95%CI €3678, €3987) and ≥75 years ASA III-IV laparoscopic (95%CI €3089, €3357).

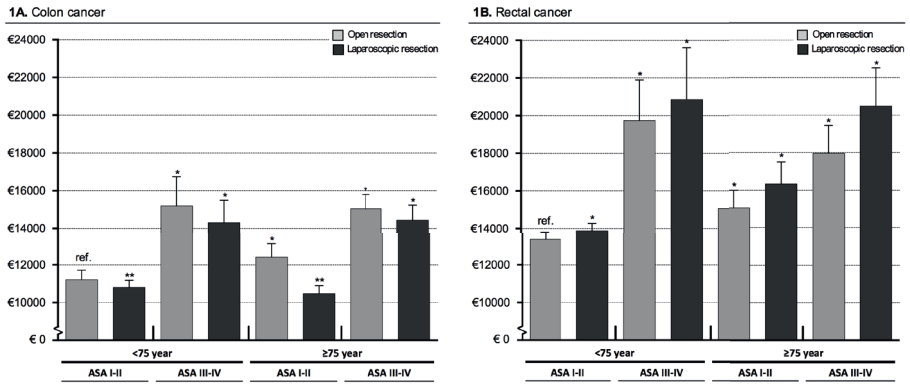

Figure 1. Total costs of colon and rectum cancer resections stratified by sub-group
1A. Colon cancer
1B**.** Rectal cancer
Abbreviations: ASA, American Society of Anesthesiologists classification. Error bar shows standard error of the mean. * Significant more expensive (p<0.05.) as compared to reference subgroup (ref = <75year ASA I-II). ** Significant less expensive (p<0.05.) as compared to reference subgroup (ref = <75year ASA I-II).

All four laparoscopic subgroups had significant lower total hospital costs as compared with the open resection groups with the same age and ASA score, ranging from -€409 for <75 years ASA I-II to -€1932 for ≥75 years ASA I-II patients (Figure 2). The largest differences in clinical as well as financial outcomes between the two surgical approaches were seen in the subgroup ≥75 years ASA I-II; laparoscopic resection was associated with 46.0% less mortality (p=0.05), 41.1% less severe complications (p<0.001), 25.2 % less LOS (p=0,013), 64.5% less ICU LOS (p<0,001) and 15.6% lower hospital costs (p<0,001) as compared to open resection (Table 2).

See for all details regarding mortality, severe complications, hospital costs, LOS and operation time between open and laparoscopic colon cancer resections Table 2.
Of all laparoscopic colon resections, 283 resections (11.9%) were converted to an open resection. Mean hospital costs of all converted colon resections (€13903) were 10% (€1209) higher than costs of open colon resections (€12694) (95%CI €1173, €1246, p<0.001).

Rectal Cancer

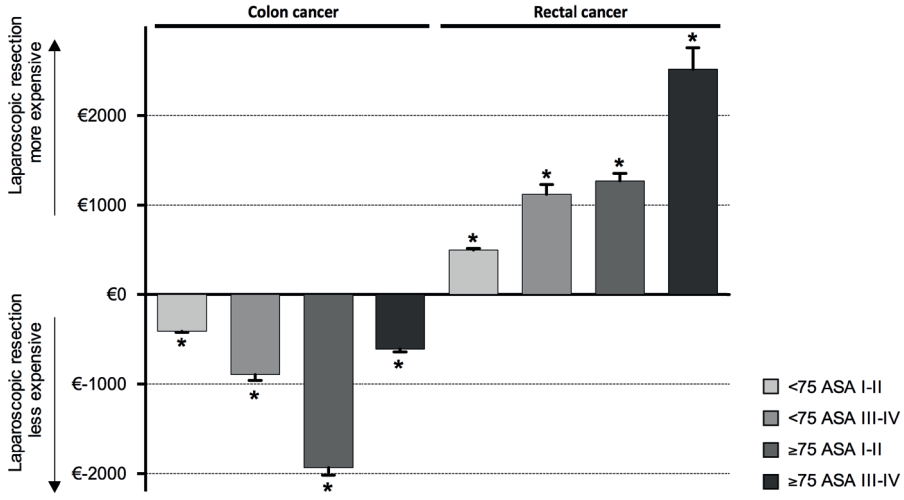

Figure 2. Cost difference between laparoscopic and open resections stratified by sub-group
Abbreviations: ASA, American Society of Anesthesiologists classification. Error bar shows 95% upper confidence interval. * Significant difference between open and laparoscopic resections (p<0.001).

For rectal cancer, 1113 (47.8%) patients underwent an open resection and 1215 (52.2%) patients underwent a laparoscopic resection (Table 1). The largest subgroup was <75 years ASA I-II (691 open vs 820 laparoscopic procedures) and the smallest subgroup was <75 years ASA III-IV (103 open vs 82 laparoscopic procedures).
Subgroup <75 years ASA I-II open was used as a reference group (Figure 1B). Care provided to patients in each of the remaining subgroups was more expensive than that of the reference group: <75 years ASA I-II laparoscopic (95%CI €483, €519), <75 years ASA III-IV open (95%CI €6066, €6695), <75 years ASA III-IV laparoscopic

(95%CI €7125, €7874), ≥75 years ASA I-II open (95%CI €1623, €1781), ≥75 years ASA I-II laparoscopic (95%CI €2838, €3112), ≥75 years ASA III-IV open (95%CI €4389, €4839) and ≥75 years ASA III-IV laparoscopic (95%CI €6776, €7483).
All four laparoscopic subgroups had significant higher total hospital costs for resection as compared with the open subgroups with similar age and ASA, ranging from +€501 for <75year ASA I-II to +€2515 for ≥75 year ASA III-IV patients (Figure 2).
The largest difference in total costs between the two procedures were seen in the subgroup of ≥75 years ASA III-IV; laparoscopic resection was associated with 14% higher hospital costs ($p<0.001$) as compared with open resection (Table 3). See for all details regarding mortality, severe complications, hospital costs, LOS and operation time between open and laparoscopic colon cancer resections Table 3.
Of the laparoscopic rectal resections, 141 resections (11.6%) were converted to an open resection. Mean hospital costs of all converted rectal resections (€16880) were 14% (€2130) higher than costs of open rectal resections (€14750) (95%CI €2046, €2213, $p<0.001$).

DISCUSSION

This population-based study shows that laparoscopic colon cancer surgery can be performed with lower hospital costs up to 90 days after discharge as compared with open surgery. In contrast, for rectal cancer surgery, laparoscopy was associated with higher costs. Furthermore, operative risk appeared to be a main determinant of hospital costs. The largest cost differences between laparoscopic and open resection could be identified for specific patient groups based on age and ASA. This is valuable data for health care providers and/ or payers, because it shows that the case mix of a colorectal cancer population and the applied surgical approach have their financial impact.

Colon cancer

For the colon cancer subgroups, cost differences between the two approaches ranged from €400 to €1900, favoring laparoscopic resection (Figure 2). The largest

cost savings from a laparoscopic approach were seen for elderly fit patients, which reflects the more favorable clinical outcome with a 46% reduction in mortality, and 41% lower severe complication rate (Table 2). In all subgroups, higher operation costs were amply compensated by lower costs in each of the other categories. This was most likely explained by the lower severe complication rate after laparoscopy, resulting in less resource utilization.

Earlier studies analyzing hospital costs after colon surgery were mostly from tertiary referral centers or RCT's with potential selection bias and restricted external validity [10,12]. So far, population-based studies on this topic were from the US [26,27]. These studies were based on claim data from payers, and therefore proxies of costs were analyzed rather than actual costs [26,27]. Cost analyses in the present study were based on uniform cost calculations for every individual patient based on TD-ABC, which is a superior method for measuring and understanding actual costs [19,20].

Rectum cancer

For rectal cancer, earlier studies analyzing hospital costs were retrieved from single center data [11,28,29], mostly reflecting the performance of dedicated surgical teams in referral centers. By the best of our knowledge, this is the first multicenter study analyzing hospital costs after rectal cancer surgery using a population-based database, reflecting routine daily practice.

Overall, the high primary operation costs for laparoscopic rectal resections did not outweigh the other type of costs (Table 3), as seen for laparoscopic colon surgery (Table 2). A possible explanation might be that laparoscopy for rectal cancer was a relatively new technique between 2010 and 2012 in the Netherlands, whereas laparoscopy for colon cancer was already routine practice. Some hospitals might still have been in their learning curve. However, only four out of nine hospitals with an average volume of more than 20 laparoscopic rectal cancer resections per year showed less costs compared to open resections (data not shown). Another explanation for the observed discrepancy in costs between colon and rectal cancer resections might be related to the anastomosis. The more high-risk anastomoses in rectal resections might reduce the impact of laparoscopy on costs in the postoperative course. In this context, it should also be mentioned that two third of low

Table 3. Clinical and financial outcomes after open and laparoscopic rectum cancer procedures stratified by subgroup

Sub group	Outcome of interest	Open	Laparoscopy	Delta	RD	OR	(95% CI)	P-value
<75Y ASA I-II	n	691	820					
	Mortality (%)	7 (1.0%)	1 (0.1%)	-0.9%	-90.0%	0.119	(0.02 , 0.97)	0.047
	Severe complication (%)	163 (23.6%)	165 (20.1%)	-3.5%	-14.8%	0.816	(0.64 , 1.04)	0.10
	Conversion rate	n/a	84 (10.2%)					
	Hospital costs	€13366	€13867	€501	4%	n/a	(€483 , €519)	<0.001
	- OR costs (primary OR)	€3393	€4571	€1178	35%			
	- ICU costs	€1437	€1066	-€371	-26%			
	- Ward costs	€5686	€5544	-€142	-2%			
	- Other costs	€2849	€2685	-€164	-6%			
	LOS	12.3	10.9	-1.4	-11%	n/a	(-1.51 , -1.28)	<0.001
	- LOS ICU	0.8	0.5	-0.3	-33%	n/a	(-0.35 , -0.14)	<0.001
	Primary OR time (min)	213	236	23	10.8%	n/a	(0.28 , 0.49)	<0.001
<75Y ASA III-IV	n	103	82					
	Mortality (%)	4 (3.9%)	2 (2.4%)	-1.5%	-38.5%	0.619	(0.11 , 3.47)	0.59
	Severe complication (%)	32 (32.7%)	32 (40.0%)	7.3%	22.3%	1.429	(0.78 , 2.62)	0.25
	Conversion rate	n/a	21 (25.6 %)					
	Hospital costs	€19746	€20865	€1119	5.7%	n/a	(€1005 , €1234)	<0.001
	- OR costs (primary OR)	€3495	€4975	€1480	42%			
	- ICU costs	€4834	€4250	-€584	-12%			
	- Ward costs	€7006	€7124	€118	2%			
	- Other costs	€4411	€4515	€104	2%			
	LOS	15.9	14.7	-1.2	-7%	n/a	(-1.41 , -0.86)	<0.001
	- LOS ICU	2.3	2.0	-0.3	-13%	n/a	(-0.59 , -0.01)	<0.001
	Primary OR time (min)	216	257	41	19.1%	n/a	(0.39 , 0.99)	<0.001

Table 3. Clinical and financial outcomes after open and laparoscopic rectum cancer procedures stratified by subgroup (continued)

Sub group	Outcome of interest	Open	Laparoscopy	Delta	RD	OR	(95% CI)	P-value
≥75Y ASA I-II	n	202	220					
	Mortality (%)	5 (2.5%)	4 (1.8%)	-0.7%	-28.0%	0.730	(0.19 , 2.76)	0.64
	Severe complication (%)	65 (32.2%)	52 (23.6%)	-8.6%	-26.7%	0.652	(0.43 , 1.00)	0.05
	Conversion rate	n/a	23 (10.5%)					
	Hospital costs	€15068	€16340	€1272	8%	n/a	(€1188 , €1357)	<0.001
	- OR costs (primary OR)	€3105	€4278	€1173	38%			
	- ICU costs	€2575	€2298	-€277	-11%			
	- Ward costs	€6597	€6649	€52	1%			
	- Other costs	€2790	€3115	€325	12%			
	LOS	15.9	13.6	-2.3	-14%	n/a	(-2.51 , -2.02)	<0.001
	- LOS ICU	1.4	1.1	-0.3	-23%	n/a	(-0.52 , -0.14)	<0.001
	Primary OR time (min)	203	229	27	13.1%	n/a	(0.25 , 0.64)	<0.001
≥75Y ASA III-IV	n	117	93					
	Mortality (%)	11 (9.4%)	7 (7.5)%	-1.9%	-20.2%	0.784	(0.29 , 2.11)	0.63
	Severe complication (%)	43 (36.8%)	34 (36.6%)	-0.2%	-0.5%	0.992	(0.56 , 1.75)	0.98
	Conversion rate	n/a	13 (14.0%)					
	Hospital costs	€17980	€20495	€2515	14%	n/a	(€2274 , €2758)	<0.001
	- OR costs (primary OR)	€3264	€4460	€1196	37%			
	- ICU costs	€4568	€4842	€274	6%			
	- Ward costs	€6666	€6980	€314	5%			
	- Other costs	€3482	€4213	€731	21%			
	LOS	15.2	17.4	2.2	15%	n/a	(1.85 , 2.55)	<0.001
	- LOS ICU	2.2	2.7	0.5	23%	n/a	(0.23 , 0.78)	<0.001
	Primary OR time (min)	197	241	44	22.4%	n/a	(0.45 , 1.02)	<0.001

Abbreviations: AD, absolute difference; RD, relative difference; OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists classification.

anastomoses are diverted in the Netherlands, while this is seldom performed for a colonic anastomosis. A stoma may interfere with quick recovery (and discharge) after minimally invasive surgery and can have a significant influence on costs related to stoma specific complications, reinterventions, and use of materials.
Total hospital costs after rectal cancer resection were lowest for patients under the age of 75 years and ASA score I-II undergoing an open resection (€13,366) and highest for patients under the age of 75 years and ASA score I-II undergoing an open resection (€13,366) and highest for patients under the age of 75 years with ASA score III-IV undergoing a laparoscopic resection (€20,865) (Figure 1B). The high total costs for the young but comorbid patients (both laparoscopic and open) may represent an aggressive treatment of complications which might have prevented postoperative mortality. This is supported by a low failure to rescue patients who suffer from severe complications in this patient category (6 out of 64 = 9.4%) as compared with those of 75years or older with ASA score III-IV (18 out of 77= 23.4%) (Table 3).

Earlier studies analyzing hospital costs after colorectal cancer surgery did not stratify for different groups of patients [8-11,26-33]. In fact, many studies did not even stratify for colon or rectal cancer [8,30-33]. This makes interpretation difficult, because colon and rectal cancer are different disease entities in several aspects, and overall analysis does not give any insight into clinically relevant risk groups. For both colon and rectal cancer procedures, ASA classification had a strong effect on hospital costs, relatively independent of age and surgical approach (Tables 2 and 3). This correlates with an earlier study of our group showing that ASA score III and IV are strong independent contributors to high hospital costs when performing colorectal cancer resection s[34]. The inclusion of these fragile patients in our study reflects daily practice and therefore supports the use of population-based registries as a source of research data [13].
The conversion rate for laparoscopic colon procedures (11.9%) was comparable with rectum procedures (11.6%). When comparing converted laparoscopic procedures to initial open procedures, converted resections were more expensive (for colon and rectum procedures respectively a 10% and 14% increase in costs).

This is mainly because converted procedures receive the disadvantages of both approaches: higher operation costs as seen in laparoscopic surgery combined with longer length of hospital stay as seen in open surgery (data not shown). Clinical outcomes of converted procedures in this study (data not shown) were comparable with the clinical outcomes of open procedures. This is similar to the findings of an earlier study from our group analyzing all Dutch colorectal cancer procedures in 2010 [6] and showing no significant differences between converted laparoscopic procedures and open procedures. This means that if more adequate pre-operative patient selection could lead to lower conversion rates, it might reduce hospital costs as well.

By measuring hospital costs at patient level, this study highlights the variation in total hospital costs between the clinical subgroups, ranging from €10,474 (≥75years ASA I-II colon cancer patients) to €20,865 (<75 years ASA III-IV rectal cancer patients), which is a 99% difference. In the Netherlands, no different reimbursement exists between colon and rectal cancer patients; neither differentiation is made based on age or ASA classification. Referral of rectal cancer patients to specialized centers for surgery has its impact on hospital's budgeting, as five out of eight rectal cancer subgroups (both open and laparoscopic) were more expensive as compared with the most expensive colon cancer subgroup (Figure 1). Moreover, irrespective of location of tumor, hospitals with a catchment area in which many frail and/or older patients live, might suffer from this rigid reimbursement system.

Limitations

A known limitation of retrospective studies is the occurrence of coding- or documentation errors in large databases, which might affect data integrity. However, as these errors should effect both treatments (open and laparoscopic) we do not believe that this affected our main conclusions. Second, information about experience of the operating surgeon is not listed in the DSCA. One might argue that specialization of the operating surgeon rather than the operative technique itself explains outcome differences. However, in most Dutch hospitals and especially in the elective setting, both open and laparoscopic colorectal resections are performed by specialized colorectal surgeons. Third, costs of specialists' fees, medication, and

dialyses were excluded in our analyses. This might underestimate total costs in both groups. Finally, previous abdominal surgery is not specified in the DSCA. Including or excluding patients with previous abdominal surgery did not influence outcome comparisons between laparoscopic and open resection in a previous study from our group [14]. Therefore we included those patients in our analyses.

We did not consider costs outside the hospital and beyond 90 days postoperatively, although recent literature suggests that laparoscopic approach for colon resections might result in additional out of hospital and/or long-term savings as well. For example, patients undergoing laparoscopic colon resection were more likely to be discharged home without nursing care [27]. Moreover, quick recovery will result in earlier participation in the labor process and will reduce indirect healthcare costs as well. Considering recent long-term data from the LAFA study, further cost reduction after laparoscopic colon resection can be expected because of a reduced readmission and reoperation rate for adhesion related small bowel obstruction and incisional hernia [5].

CONCLUSIONS

This population-based study revealed that laparoscopic resections for colon cancer can be performed with lower hospital costs up to 90 days after discharge as compared with open resections. For rectal cancer, healthcare providers should be aware of the higher costs after laparoscopic resection, which might be of use when negotiating annual contracts with payers. Finally, hospitals (and their payers) serving relatively high number of frail, and in less extent older, colorectal cancer patients should also be aware of the accompanying increased hospital costs.

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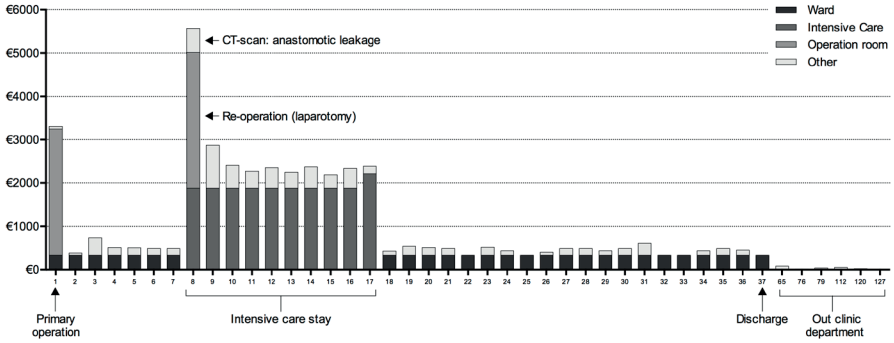
SUPPLEMENTAL MATERIAL – FIGURE LEGEND



Supplemental figure 1. Clinical and financial course of a colon cancer patient
A. Illustrative picture of a 79 year, ASA III, female patient with a caecum cancer undergoing a laparoscopic ileocaecal resection (day 1). Cost of primary admission (day 1 till day 41) were €42 274. Cost during Q1 (first 90 days after discharge) were €216.
B. Different categories of resources extracted from the Hospital Information System.

Category	Examples within category
Operation	Surgery time, operation room session
Ward	Inpatient ward days
Intensive care	Intensive Care Unit days, Medium Care Unit days, Cardiac Care Unit days
Other	
- Radiology	Ultra sound, X-ray, CT scan, MRI scan
- Laboratory	Activities related to pathology, haematology, clinical chemistry, microbiology
- Consulting	Consults other medical specialist, outpatient department visits
- Materials	Blood products, prostheses and implants
- Other	Electrocardiography, spirometry, physiotherapy, medical rehabilitation