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

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CHAPTER 8

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HOSPITAL COSTS OF COLORECTAL CANCER SURGERY FOR THE OLDEST OLD: A DUTCH POPULATION-BASED STUDY

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ABSTRACT

Background and Objectives

Due to increasing healthcare costs, discussions regarding increased hospital costs when operating on high-risk patients is rising. Therefore, the aim of this study was to analyze if oldest-old colorectal cancer patients have a greater impact on hospital costs than their younger counterparts.

Methods

All colorectal cancer procedures performed in 29 Dutch hospitals between 2010 and 2012 and listed in the Dutch Surgical Colorectal Audit were analyzed. Oldest-old patients (≥85 years) were compared to patients <85 years. Ninety-day hospital costs were measured uniformly in all hospitals based on time-driven activity-based costing.

Results

Compared to <85-year-old patients (n = 9130), the oldest old (n = 783) had longer hospital stays (LOS) (11.3 vs 13.2, $p < 0.001$), more severe complications (21.8% vs 29.0%, $p < 0.001$), more failure to rescue (13.9% vs 37.0%, $p < 0.001$) and higher mortality (3.0% vs 10.7%, $p < 0.001$). Deceased oldest-old patients had significantly less LOS and less LOS ICU. Total hospital costs were 3% lower for oldest-old patients (€13168) than for <85-year-old patients (€13644, $p < 0.001$). In cases of severe complications or death, hospital costs for the oldest old were 25% and 31% lower than those of < 85-year-old patients (both $p < 0.001$).

Conclusion

Although frequently assumed to be more expensive, operating on oldest-old patients with colorectal cancer does not increase hospital costs compared to younger patients. This was most likely due to faster deterioration or less aggressive treatment of oldest-old patients when (severe) complications occurred.

INTRODUCTION

Due to increasing life expectancy and earlier detection programs, the incidence of colorectal cancer is increasing rapidly [1,2]. Surgery for colorectal cancer is associated with a disproportional share of adverse events compared to general surgery [3], and its complications are responsible for a tremendous increase in hospital costs [4]. Although the oldest old are at risk for developing complications after colorectal cancer procedures [5,6], earlier studies show that surgery remains the treatment of choice for this subgroup [7,8].

As of 2009, all Dutch colorectal cancer patients undergoing a resection are listed in a nationwide database (The Dutch Surgical Colorectal Audit, DSCA) [9]. Although the (daily) decision-making over whether a patient can undergo an operation is primarily based on clinical arguments, there is still an ongoing discussion regarding increased hospital costs when operating on high-risk and/or frail patients. Moreover, because the Dutch health care system is struggling with rising costs (its expenditure rose to more than 13% of the gross domestic product in 2012 [10]), one might argue that operating on the oldest old for colorectal cancer might result in an impermissible misbalance in the use of hospital resources. To facilitate this discussion, the aim of this study was to analyze if the oldest old (age ≥85 years) colorectal cancer patients have a greater impact on hospital costs than their younger counterparts.

METHODS

Data collection

The data used for this study was retrieved from a combined clinical and financial dataset in the Dutch Value Based Healthcare Study. A detailed description of inclusion of hospitals (n = 29) and matching of the clinical and the financial dataset has been described recently [11].

The clinical data set was retrieved from the DSCA, a population-based database in which detailed patient, tumor, diagnostic, procedural and outcome data are

registered for all patients undergoing a resection of a primary colorectal carcinoma in the Netherlands [9,12].

The economic evaluation was conducted from a hospital perspective. Therefore, only 'in-hospital' costs were considered. Costs were taken into account from the day of initial surgery until discharge (= primary admission) up to 90 days after discharge (= Q1). Resource utilization at the patient level (e.g., laboratory orders, operation room time or ward days, see Supplemental Table 1) was extracted from the Hospital Information System from each participating hospital. For each hospital, the translation of patient level resource utilization into costs was provided by Performation (Bilthoven, The Netherlands), a healthcare consultancy firm providing patient level costing and benchmarking products for more than 100 hospitals across Europe [13]. Costs were calculated using Time-Driven Activity-Based Costing (TD-ABC) [14], which is a bottom-up micro-costing 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 [15,16]. The cost price calculations have been standardized by Performation, and therefore uniformity in methodology exists between all participating hospitals. The most recent cost price model (2012) for each hospital was used for all three years (2010, 2011, and 2012) to avoid differences due to inflation or the different models themselves. Different activities are grouped into eight categories, as shown in Supplemental Table 1. Specialists' fees, medication and dialysis costs were excluded because these parameters were not uniform in the participating hospitals, which made equal comparisons impossible.

Definitions

The oldest old patients were defined as any patient age 85 or older. As a reference group, all patients <85 years old were used. The cutoff age of 85 was determined based on an earlier review stating that age >85 years was related to significantly more mortality and morbidity, such as pulmonal and cardiovascular complications [7]. This was recently confirmed in the DSCA, which showed that the risk of 30-day mortality increases to 10% for patients ≥85 years compared to 1% of patients <70

years and 4% for patients 70-84 years old [5]. For the sub-analyses, extremely old patients were defined as patients aged 90 or older, and patients who were 85-90 years old were used as a reference group.

The outcome measures for quality of healthcare included postoperative mortality, which was defined as in-hospital death or death within 30 days after surgery; any complications, which were defined as complications occurring during admission or within 30 days after surgery; severe complications, which were defined as complications occurring during admission or within 30 days after surgery that led to mortality, reintervention (operative or percutaneous), or a prolonged hospital stay of 14 days or more; anastomotic leakage/abscess; reintervention (surgical, radiological, or endoscopic); failure to rescue (FTR), which was defined as the percentage of patients with severe complications who died in-hospital or within 30 days after resection [17]; R1/R2 resection; resections in which fewer than 10 lymph nodes were retrieved; length of hospital stay (LOS, starting from day of operation = day 0) and LOS ICU. Financial measures were the total costs (primary admission up to 90 days after discharge; costs of primary admission; costs of Q1 (= first 90 days after discharge) and total costs (primary admission and Q1) by category (as mentioned in Supplemental Table 1).

Analysis

A chi-square test and One-way ANOVA were used to investigate the differences between patient characteristics in the two groups (Table 1). Absolute clinical and financial outcomes were presented as unadjusted (no risk-adjustment was used due to the descriptive focus of this study). The significance level of the univariable analysis was set at a two-tailed P-value of 0.05. The odds ratio (OR) along with the 95% confidence interval was calculated for each clinical binary outcome. The raw difference between the two groups ("unstandardized" mean difference) together with a confidence interval was computed to compare non-normal continuous outcomes (hospital costs and LOS) [18]. The use of the "unstandardized" mean difference may be used when the outcome was not normally distributed. Statistical analyses were performed using SPSS (version 20; IBM) and R (version 18). The outcomes are presented as the mean.

Table 1. Patient, tumor and operations characteristics

		<85 year		≥85 year		
		n	%	n	%	
N (% of total)		**9130**	**92.1%**	**783**	**7.9%**	**p-value**
Patient and tumor characteristics						
Age (mean in year)			68.4		87.6	<0.001
Male		5143	56.3%	328	41.9%	<0.001
BMI (mean in kg/m^2)			26.2		25.0	<0.001
Charlson score	Charlson 0	5018	55.0%	291	37.2%	<0.001
	Charlson 1	2045	22.4%	220	28.1%	
	Charlson 2+	2067	22.6%	272	34.7%	
ASA score	I-II	7077	77.8%	391	50.3%	<0.001
	III	1880	20.7%	359	46.1%	
	IV-V	136	1.5%	28	3.6%	
Tumor location	Right colon	2804	30.7%	382	48.4%	<0.001
	Left colon	1051	11.5%	100	12.8%	
	Sigmoid	2494	27.3%	179	22.9%	
	Rectum	2781	30.5%	122	15.6%	
Tumor stage (TNM)	Stage 0	164	1.8%	5	0.6%	<0.001
	Stage 1	616	6.8%	30	3.9%	
	Stage 2	1924	21.2%	153	19.7%	
	Stage 3	4984	55,0%	470	60.4%	
	Stage 4	1200	13.2%	112	14.4%	
	Unknown	172	1.9%	8	1,0%	
Preoperative	None	446	16.0%	39	32.0%	<0.001
-radiotherapy*	5 x 5 Gy	1282	46.1%	76	62.3%	
	Long course**/ else	1053	37.9%	7	5.7%	
Double tumor	Yes	300	3.3%	25	3.2%	0.02
Distant metastases	Yes	985	10.8%	53	6.8%	<0.001
Operation characteristics						
Emergency resection		1161	12.7%	173	22.1%	<0.001
Laparoscopic		4302	47.4%	277	35.6%	<0.001
Conversion (LR only)		585	13.6%	36	13,0%	0.08
Metastasectomy		278	3.0%	12	1.5%	0.02
Extended resection		779	8.5%	66	8.4%	0.92
Anastomosis/ stoma	Stoma	1791	20.3%	211	28,0%	<0.001
	Anastomosis	5804	65.9%	515	68.4%	
	Anastomosis & stoma	1209	13.7%	27	3.6%	
Operation time (mean) ***			3.07		2.65	<0.001

* Rectum only. ** Long course = 28x1.8Gy/ 25x2.0Gy ***Operation time for primary operation in hour is shown. Abbreviations: BMI, Body Mass Index; ASA, American Society of Anesthesiologists risk score; Left colon, including transverse colon; TNM, Classification of Malignant Tumors; Gy, gray; LR, Laparoscopic resection.

RESULTS

A total of 9,913 patients were eligible for analysis. Of those patients, 9,130 patients were aged <85 years, and 783 patients were aged ≥85 years. All analyzed patient, tumor and procedure characteristics of the studied population are shown in Table 1. In particular, patients ≥85 years and older were less frequently operated on for rectal cancer (16% vs 31%), received less frequent pre-operative radiotherapy (68% vs 84%), had fewer metastases (6.8% vs 10.8%), were more often operated on in an emergency setting (22% vs 13%), received an anastomosis with a stoma less often (4% vs 14%) and were more likely to receive a primary stoma (28% vs 20%) than patients <85 years.

Clinical outcomes

The overall mortality rate was significantly higher for all ≥85-year-old patients (elective and emergency) than for the <85-year-old patients (10.7% vs 3.0%, OR 3.855, CI 2.984-4.980, $p < 0.001$) as well as in elective settings (7.4% vs 2.4%, OR 3.201, CI 2.281-4.493, $p < 0.001$). In addition, any complications, severe complications, reintervention, FTR, R1/R2 resections, LOS and LOS ICU were significantly higher for ≥85-year-old patients than for <85-year-old patients. LOS and LOS ICU for deceased patients were significantly lower for ≥85-year-old patients than for <85-year-old patients. Anastomotic leakage and resections in which fewer than 10 lymph nodes were retrieved did not differ significantly between the two groups (Table 2).

Financial outcomes

Total hospital costs for ≥85-year-old patients were 3% lower compared to <85-year-old patients (€13,168 vs €13,644, difference €476 and corresponding 95%CI €469-483, $p < 0.001$). Costs related to operations, radiology, laboratory, consulting and other costs were lower for ≥85 year-old patients than for <85-year-old patients. Costs related to the ward, intensive care and materials were higher for ≥85-year-old patients compared to <85-year-old patients (Table 3). There was minimal difference in the hospital costs of patients operated in an elective setting, living patients and patients without severe complications, which were slightly lower for ≥85-year-old patients (respectively -0.3%, -5% and +3%) (Table 3).

Table 2. Clinical outcomes

	<85 year		≥85 year		Difference				
	n	%	n	%					
N (% of total)	9130	92,1%	783	7,9%	RD	AD	OR	95% CI	p-value
Mortality	276	3.0%	84	10.7%	257%	7.7%	3.86	(2.98-4.98)	<0.001
After elective surgery	189	2.4%	44	7.4%	208%	5.0%	3.20	(2.28-4.49)	<0.001
Any complication	3017	33.0%	330	42.1%	28%	9.1%	1.48	(1.27-1.71)	<0.001
Severe complication	1987	21.8%	227	29.0%	33%	7.2%	1.47	(1.25-1.73)	<0.001
Anastomotic leakage*	485	8.4%	34	6.6%	-21%	2.2%	0.78	(0.54-1.11)	0.17
Reintervention	1297	14.2%	89	11.4%	-20%	2.8%	0.77	(0.62-0.97)	0.028
Failure to rescue	276	13.9%	84	37.0%	166%	23.1%	3.64	(2.07-4.91)	<0.001
R1/R2 resection**	309	3.5%	43	5.7%	63%	2.2%	1.65	(1.19-2.29)	0.003
<10 lymph nodes**	1869	20.7%	174	22.5%	12%	1.8%	1.11	(0.93-1.32)	0.25
LOS total (days)***		11.3		13.2	17%	1.88	n/a	(1.80-1.96)	<0.001
LOS deceased patients (days)***		16.2		13.2	-19%	3.01	n/a	(2.68-3.34)	<0.001
LOS ICU (days)***		1.3		1.6	23%	0.26	n/a	(0.19-0.34)	<0.001
LOS ICU deceased patients (days)***		7.8		4.5	-42%	3.21	n/a	(2.87-3.55)	<0.001

*Only patients with a primary anastomosis (without stoma) are evaluated. ** missing cases were excluded. ***mean LOS (total and ICU) of primary admission is shown. Abbreviations: LOS, Length of stay. ICU, Intensive Care Unit. RD, relative difference. AD, absolute difference.

Table 3. Financial outcomes

	<85 year	≥85 year	Difference			
	n=9130	n=783	RD	AD	95%CI	p-value
Total costs	€13644	€13168	-3%	€476	(€469-€483)	<0.001
Operation	€3872	€3056	-	-	-	-
Ward	€4997	€5289	-	-	-	-
Intensive Care	€2594	€2861	-	-	-	-
Radiology	€258	€175	-	-	-	-
Laboratory	€775	€704	-	-	-	-
Consulting	€421	€313	-	-	-	-
Material	€221	€274	-	-	-	-
Other	€505	€496	-	-	-	-
Total cost of living patients	€13256	€12587	-5%	€669	(€660-€678)	<0.001
Total cost without severe complications	€9622	€9899	3%	€277	(€273-€281)	<0.001
Total cost elective resections	€13287	€13244	0%	€43	(€42-€44)	<0.001

Abbreviations: RD, relative difference. AD, absolute difference.

The total costs of patients operated in an emergency setting were 19% lower for the oldest old compared to <85-year-old patients (€12,938 vs €15,973, AD €3,035, 95% CI €2,920-3,150, p < 0.001). Total costs of deceased patients were 31% lower for the oldest old compared to <85-year-old patients (€17,999 vs €26,093, AD €8,094, 95% CI €7,501-€8,687, p < 0.001). The total costs of patients with a severe complication were 25% lower for the oldest old compared to <85-year-old patients (€21,174 vs €28,105, AD €6,931, 95% CI €6,277-€7,135, p < 0.001) (Figure 1).

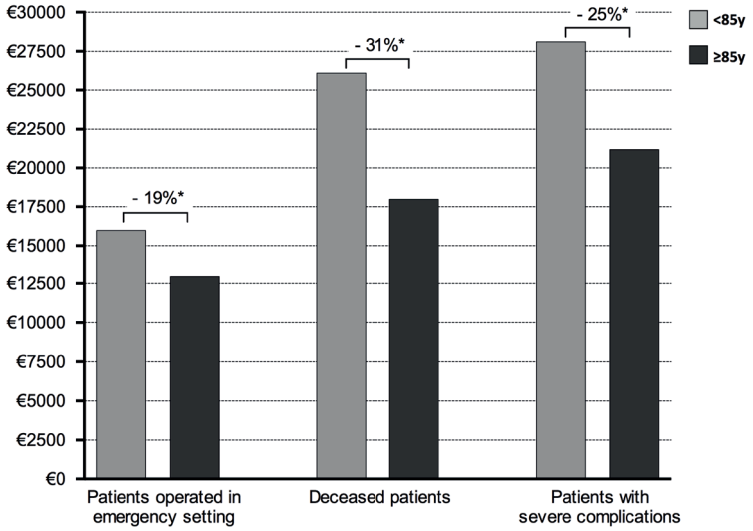

Figure 1. Lower hospital costs for oldest old patients operated in emergency setting and with a complicated course
Total hospital costs of resections in emergency setting, resections leading to death and resections leading to severe complications stratified by age group. * Significant difference, p < 0.001.

Outcomes of patients between 85-90 and ≥90 years old

From the oldest old, a total of 155 patients were classified as "extreme old." The mean age of patients 85–90 (n = 628) was 86.6 years and for ≥90-year-old patients was 91.5 years. In this study, the clinical outcomes did not differ significantly between the extreme old and patients 85–90 years old (except for R1/R2 resection and LOS/ LOS ICU stay) (Table 4). All extreme old patients and deceased extreme old patients had significantly lower costs compared to 85-90-year-old patients and deceased 85-90-year-old patients (respectively -2% and -27%) (Table 5).

Table 4. Outcomes of patients between 85-90 year vs ≥90 year

	85-90 year		≥90 year		Difference				
	n	%	n	%					
N (% of total)	628	80.2%	155	19.8%	RD	AD	OR	95% CI	p-value
Mortality	69	11.0%	15	9.7%	-12%	1.3%	0.87	(0.48-1.56)	0.64
After elective surgery	37	7.3%	7	6.8%	-7%	0.5%	0.92	(0.40-2.14)	0.85
Any complication	267	42.5%	63	40.6%	-4%	1.9%	0.93	(0.65-1.32)	0.67
Severe complication	184	29.3%	43	27.7%	-5%	1.6%	0.93	(0.63-1.37)	0.70
Anastomotic leakage*	29	7.0%	5	4.9%	-30%	2.1%	0.67	(0.25-1.79)	0.43
Reintervention	73	11.6%	16	10.3%	-11%	1.3%	0.88	(0.49-1.55)	0.65
Failure to rescue	69	37.5%	15	34.9%	-7%	2.6%	0.89	(0.45-1.79)	0.75
R1/R2 resection**	29	4.8%	14	9.2%	92%	4.4%	1.99	(1.02-3.87)	0.04
<10 lymph nodes**	142	22.8%	32	20.9%	-8%	1.9%	0.89	(0.58-1.38)	0.61
LOS total (days)***	13.0	n/a	13.8	n/a	6%	0.78	n/a	(0.60-0.96)	<0.001
LOS deceased patients ***	12.7	n/a	15.5	n/a	22%	2.75	n/a	(2.04-3.46)	0.13
LOS ICU (days)***	1.7	n/a	1.2	n/a	-30%	0.45	n/a	(0.27-0.63)	<0.001
LOS ICU deceased patients (days)***	5.2	n/a	1.5	n/a	-71%	3.74	n/a	(2.90-4.50)	<0.001
Total costs	€13409	n/a	€12190	n/a	-2%	€1220	n/a	(1159-1280)	<0.001
Total costs deceased patients	€18922	n/a	€13751	n/a	-27%	€5171	n/a	(4377-5964)	<0.001

*Only patients with a primary anastomosis (without stoma) are evaluated. ** missing cases were excluded. ***mean LOS (total and ICU) of primary admission is shown. Abbreviations: LOS, Length of stay. ICU, Intensive Care Unit. RD, relative difference. AD, absolute difference.

DISCUSSION

This is the first multicenter study analyzing hospital costs for the oldest old receiving colorectal cancer surgery. The findings in this study contradict our hypothesis because surgery for the oldest old colorectal cancer patients did not lead to increased hospital costs. Because cases registered in the DSCA reflect "real world" surgical selection, the conclusions based on this study emphasize that (short-term) financial arguments should not play a major role in clinical decisions about whether to operate on the oldest old.

As described earlier, people older than 85 years old are a subgroup of frail patients that have a high rate of complications and mortality after colorectal cancer surgery compared to their younger counterparts [5-7]. This trend was also observed in our study with a tremendous increase in mortality (+257%, $p < 0.001$) and severe complications (+33%, $p < 0.001$) (Table 2). Probably, the most straightforward explanation is that this group of patients experiences the comorbidities listed in Table 1. High age itself (or other factors not listed in the DSCA) may be responsible for this increase as well, as shown by an earlier study of our group analyzing independent risk factors for severe complications after colorectal cancer surgery [4]. Poor outcomes in the oldest old might also be related to the higher number of emergency resections compared to patients under 85 years old (22% vs 13%, Table 1). One reason might be a more frequent 'wait and see' policy in the oldest old, which resulted in more tumor-related acute bowel obstructions and therefore more emergency resections. This poor prognosis after emergency resections in the elderly is also seen in the literature, which results in high-risk procedures with mortality rates up to 41% [19]. As shown in Table 4, no significant differences were seen for (almost all) clinical outcomes of patients aged 90 years and older compared to patients between 85 and 90 years old. This outcome supports the idea that careful selection for surgery in this subgroup of extreme old patients could be justified as well.

The total hospital costs of the oldest old and patients under 85 years old were both between €13,000 and €14,000, although there was an essential difference in how these total costs were accrued (Table 3). When looking at the three major drivers

behind total costs (costs related to ward, operation and ICU), we identified that patients under 85 years old had lower costs related to the ward and ICU. This result corresponds to a shorter length of hospital stay and less severe complications in this group, which resulted in less ward and ICU utilization. However, the oldest old patients had lower total costs, which was mainly determined by lower costs related to the operation. This result could be explained by the shorter duration of the primary operation (Table 1) and by the shorter duration of other operations during the first 90 days of discharge (data not shown). Another explanation for the low total hospital costs might be that oldest old patients deteriorated faster or were treated less aggressively when severe complications occurred. This possibility was reflected in a high mortality rate but is perhaps better illustrated by a significantly higher failure to rescue rate: after a severe complication, 14% of the patients under 85 years old died, whereas in the oldest old, 37% died (+166%, $p < 0.001$) (Table 2). This result was underlined by the relatively low hospital costs of the oldest old when only looking at patients experiencing severe complications. In this subgroup, the total hospital costs of the oldest old were 25% lower compared to the younger group, which reflected less hospital resource utilization (Figure 1). Additionally, hospital costs after emergency resections for the oldest old were lower than in the younger group (Figure1). Finally, when looking at deceased patients only, the length of hospital stay and length of ICU stay were significantly shorter (19% and 42%, respectively) for the deceased oldest old than for deceased patients under 85 years old (Table 2), which suggested that earlier cessation of treatment occurred. That said, it remains difficult to conclude from our study whether a high mortality rate in the oldest old was the result of less aggressive treatment (and therefore less resource utilization) or if faster deterioration resulted in high mortality rates and therefore caused less resource utilization (i.e., the chicken and egg debate).

The high mortality and morbidity rates after colorectal cancer surgery for the oldest old patients indicated the need for constructive pre-operative counseling. Ideally, scheduling for surgery, especially for the oldest old, should be based on shared decision-making, which is something that is (at the moment) inconsistently performed in the Netherlands [20]. Moreover, as shown in a recent survey among European surgeons, pre-operative screening for the frailty of old cancer patients

is poorly performed, and collaboration with geriatricians is uncommon [21]. A recent review of the literature showed evidence for the correlation between frailty and post-operative mortality, and the review authors concluded that assessment of frailty should be added to the pre-operative risk assessment in older patients [22]. Identifying the frailest old patients and developing targeted improvement programs in collaboration with geriatricians for this group might therefore be a strategy for healthcare providers to reduce complications (and therefore hospital costs).

Limitations

First, the costs of medication and specialist fees were excluded from our analyses. This may have resulted in an underestimation of the total costs for the oldest old because comorbidities in this group were higher (and therefore probably utilization of medication as well) (Table 1). However, this effect might be compensated for by lower costs related to specialists' fees, because operation times in the oldest old were shorter (Table I), and perhaps by lower costs for dialysis due to less aggressive treatment in the oldest old. Second, the DSCA is a nationwide registry (92 hospitals), although only 29 hospitals were included in this study. This decision to focus on specific hospitals might have introduced a bias in hospital and patient selection. However, this selection was solely based on whether a hospital provided detailed cost-price information to Performation (see method section), and the distribution of patients under 85 years and over 85 years in the Dutch Value Based Healthcare study database was comparable to that in the DSCA nationwide database (7.9% oldest old patients in this study (Table 1) versus 7.7% nationwide [5]). Finally, we did not have any information about colorectal cancer patients who received a conservative treatment or no treatment (e.g., radiotherapy only for old/frail rectum cancer patients) because these patients were not registered in the DSCA. Especially in the case of treating oldest old patients, information about the non-operative patients might have provided valuable insights.

Future perspectives

First, oldest old colorectal cancer patients undergoing a resection experience high 30-day mortality (10%) and high two-year mortality rates (36%) [5]. High excess one-

year mortality (especially for the elderly) after a colorectal cancer procedure is typically due to the prolonged impact of the surgery itself [23], and if elderly patients survive the first post-operative year, they have the same cancer-related survival as younger patients [24]. Incorporating long-term outcomes in cost studies might therefore be inevitable to obtain valuable steering information for improving value in healthcare [16].

Second, it is known that severe complications after colorectal cancer surgery double hospital costs during the first 90 days after discharge compared to resections without (severe) complications [4]. It is likely that severe complications will affect costs outside the hospital, and patients suffering from complications will need more nursing care at home or will be discharged to rehabilitation facilities. These complications might lead to a significant cost burden for patients, family and society in general and underscore an important topic regarding health care payers and how the health care system is organized. For example, in a multi-payer system, payers could have incentives to enroll those who are less costly and low-risk and avoid those who are costly and high-risk. This system is the norm in the United States, and the most common form of reimbursement is fee-for-service [25]. Recent research does question the use of fee-for-service because it fosters a eat-what-you-kill mentality, which introduces pressure to increase volume and decouple payment from patient outcomes [16]. Perhaps a solution might be changing the reimbursement system, for example, by moving to 'bundled payments' as suggested by Michael Porter. 'Bundled payments' inspire teamwork and should include risk-adjustment and care guarantees that hold the provider responsible for (avoidable) complications [16]. This should encourage health care providers to achieve excellent long-term outcomes (also for the vulnerable oldest old) and to realign delivery of healthcare around value for patients.

CONCLUSION

Although oldest old patients have high rates of severe complication and mortality after colorectal cancer surgery, they do not generate higher hospital costs than

younger patients. This outcome might be due to faster deterioration or less aggressive treatment of oldest old patients when (severe) complications occur.

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SUPPLEMENTAL MATERIAL

Supplemental Table 1. 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
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