Author: Govaert, J.A.
Title: Value-based healthcare in colorectal cancer surgery : improving quality and reducing costs
Issue Date: 2017-04-06

Value-Based Healthcare in Colorectal Cancer Surgery

Improving quality and reducing costs

Johannes A. Govaert

Colofon

Value-based healthcare in colorectal cancer surgery - improving quality and reducing costs
Thesis, Leiden University, the Netherlands 2017

ISBN 978-94-6233-578-3
Cover Design: Willemien Theunissen - de Bruin
Layout and printed by: Gildeprint

Value-Based Healthcare in Colorectal Cancer Surgery

Improving quality and reducing costs

PROEFSCHRIFT

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof. Mr. C.J.J.M. Stolker,
volgens het besluit van het College voor Promoties
ter verdediging op donderdag 6 april 2017
klokke 10.00 uur

door

Johannes Arthuur Govaert
geboren te Waalwijk in 1983

Promotor
Prof. dr. R.A.E.M. Tollenaar

Copromotores
Dr. M.W.J.M. Wouters (Nederlands Kanker Instituut – Antoni van Leeuwenhoek)
Dr. M. Fiocco

Leden promotiecommissie
Prof. dr. I.H.M. Borel Rinkes (Universitair Medisch Centrum Utrecht)
Prof. dr. M.J. IJzerman (Universiteit Twente)
Prof. dr. P.L. Meurs (Erasmus Universiteit Rotterdam)
Prof. dr. E.W. Steyerberg

Deze uitgave is tot stand gekomen met financiële steun van:
Dutch Institute for Clinical Auditing, Groene Hart Ziekenhuis, Stichting Wetenschappelijk Onderzoek Heelkunde Gouda, de heer en mevrouw Govaert-van Woerden, Performation, MRDM, X-IS, Fengh Medical (Europe) B.V., Applied Medical en Chipsoft

Voor mijn lieve Carla,
op onze toekomst!

CONTENTS

CHAPTER 1

J.A. Govaert

INTRODUCTION AND OUTLINE OF THIS THESIS

INTRODUCTION

Although consistently ranked number one in the European Health Consumer Indexsince 2008[1], the Dutch Health Care System is seen as one of the most expensive healthcare systems in Europe [2,3]. In the past, countless attempts to reduce healthcare costs have been tried, like enforcing practices guidelines, capitation of hospital's budgets or making patients consumers. So far, none had much impact. Perhaps one of the reasons for the lack of success of these earlier fixes is the failure to define the overall goal: improving value for patients [4]. As defined by Michael Porter, value means the health outcomes achieved that matter to patients relative to the cost of achieving those outcomes. Moving from volume and profitability of services provided, to a high-value health care delivery system might be accomplished by following the six components of Michael Porters value agenda. First, health care providers should organize into Integrated Practice Units (IPUs). In an IPU, a dedicated team made up of both clinical and nonclinical personnel provides the full care cycle for the patient's condition. Second, clinical outcomes and costs should be measured at patient level. Third, health care providers and payers should move from 'fee for services' systems to 'bundled payments for care cycles'. Fourth, services should be provided at the right location for each service line and therefore hospitals should work together to integrate care delivery across separate facilities. Fifth, superior health care providers for particular medical conditions need to serve more patients and extend their reach through strategic expansion. Six, the preceding five components are powerfully enabled by a supporting information technology platform (Figure 1) [4].

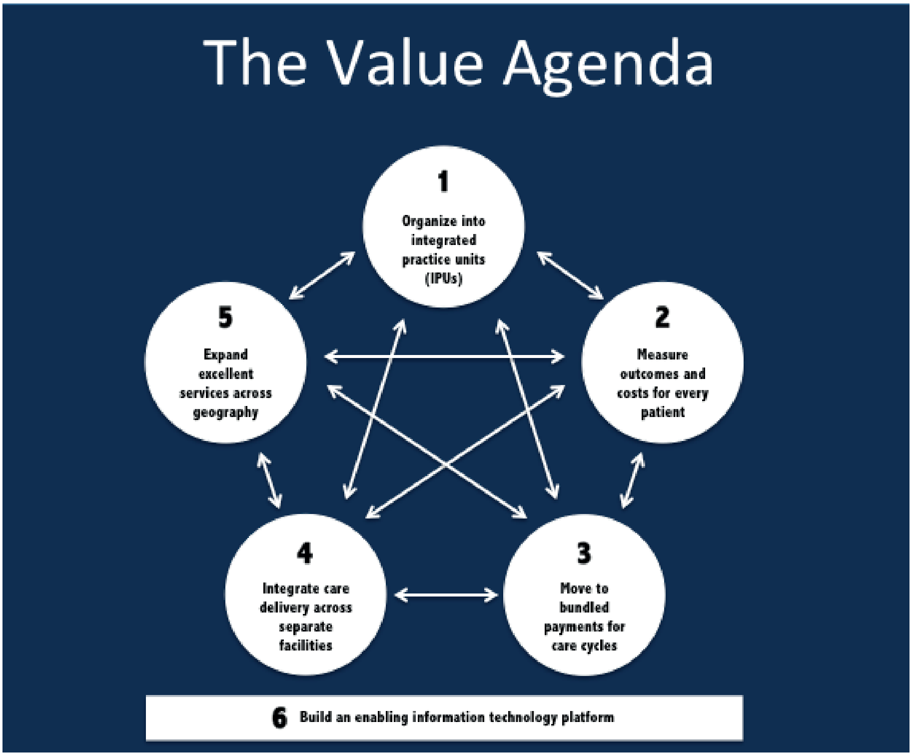


Figure 1. The Value Agenda by professor M.E. Porter
Source M.E. Porter et al. The strategy that will fix health care. Harvard Business Review 2013.

Measuring clinical outcomes for every patient

Despite the important societal and economic role the health care system fulfills, it still lags behind when it comes to standardized reporting processes. In the past, data to compare the performance of different health care providers were scarce. With Sweden as a pioneer, several nation-wide clinical registries (audits) have been initiated in the Western world, like the English Lothian and Borders large bowel cancer project and the United States National Surgical Quality Improvement Program, all leading to demonstrable improvement in clinical outcomes and smaller variation between providers [5-7]. With the introduction of the Dutch Surgical Colorectal Audit (DSCA) in 2009, robust quality information became available, enabling monitoring, evaluation, and improvement of surgical colorectal cancer care in the Netherlands.

The DSCA dataset covers 3 aspects: case-mix variables (e.g., age, sex, and comorbidity) necessary for hospital comparison; process variables (e.g., wait times, multidisciplinary team meetings, complete colonoscopy); and outcomes of care (e.g., mortality, length of hospital stay, number of lymph nodes, and complications like anastomotic leakage, pneumonia, or reinterventions) all measured at patient level. Since the introduction of the DSCA, guideline compliance for diagnostics, preoperative multidisciplinary meetings and standardized reporting increased and post-operative morbidity and mortality declined [8,9]. Besides from facilitating the improvement in outcomes, population-based databases provide important clinical data for research as well, especially from patients often not eligible for RCTs [10].

Colorectal cancer

Colorectal cancer is among the top three leading cancers in terms of new cases as well as cancer related mortality in Europe and the United States of America [11,12]. Most colorectal carcinomas develop through an adenoma - carcinoma sequence, therefore underlining the need for early detection of adenomatous polyps, e.g. by national screening programs or colonoscopy in high-risk patients. In the Netherlands between 8000-10000 procedures for primary colorectal cancer are performed each year. The cancer and nearby tissue is removed and either an anastomosis (Figure 2 or a stoma is constructed (or both, which can be more likely in the case of rectal cancer). The two major approaches for colorectal cancer surgery are open abdominal surgery, usually performed through a midline incision, or laparoscopic surgery. Between 2009 and 2015, laparoscopic approach in the Netherlands increased from 35% to 70% for colon cancer resections and from 35% to 85% for rectal cancers resections [13]. Although colorectal cancer resections are commonly performed, they are still associated with a disproportional share of complications in general surgery [14], with mortality and morbidity rates ranging up to 1.2-4.8% and 15-25% respectively [13].

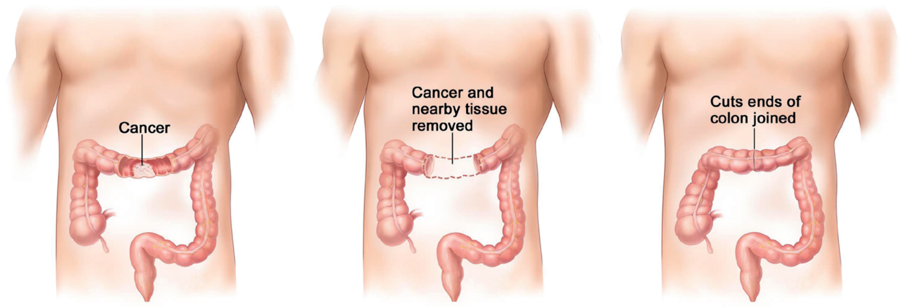


Figure 2. Colon cancer resection
Before and after a colon resection with construction of a primary anastomosis (image retrieved from the National Cancer Institute, Rockville, Maryland, United States of America).

OUTLINE OF THIS THESIS

The Dutch Value Based Health Care study

In 2012 a pilot study combined the detailed clinical data of the DSCA with cost-price information for six hospitals. Results of this pilot study led to the initiation of the Dutch Value Based Health Care (DVBHC)-study. The purpose of the DVBHC-study was to investigate possible relations between quality and costs of colorectal cancer surgery. Twenty-nine hospitals were approached for participation and analyses were performed from a scientific perspective. Translation of patient level resource utilization into costs for each hospital was provided by Performation (Bilthoven, The Netherlands), a healthcare consultancy firm providing patient level costing (using time-driving activity-based costing) [15]. The dataset of the Dutch Value Based Health Care study was used for **chapters 3, 4, 5, 7, 8 and 9**.

Surgical auditing and hospital costs

Recent literature suggests that focus in health care should shift from reducing costs to improving quality; where quality of health care improves, cost reduction will follow [16]. Surgical auditing could facilitate this process, since availability of key data on processes and outcomes is one of the cornerstones for quality improvement. However quality improvement by surgical auditing had been described earlier, it’s relation to cost reduction is poorly investigated. A systematic review of the relationship between surgical auditing and cost-evaluation is reported in **chapter 2** [17] of this thesis.

The DSCA identified significant reduction in mortality and severe complications after its initiation in 2009 [8]. To explore the effect of a nation-wide quality improvement initiative on healthcare costs, the DVBHC-database was analyzed to investigate whether the quality improvement between 2010 and 2012 for the participating 29 hospitals was accompanied by cost-reduction as well. Moreover, identification of ‘best performing hospitals’ was explored by looking at quality and costs at hospital level. The results are reported in **chapter 3** [18].

Colorectal cancer surgery is commonly performed however it is associated with a disproportionate share of adverse events in general surgery [14]. Since adverse events are associated with extra hospital costs it seems important to explicitly discuss the costs of complications and the risk factors for high-costs after colorectal surgery. Obviously, a decline in complication rates after colorectal surgery will be of most benefit to the patients, however one might argue that a business case for quality improvement can be made as well. Both items are reported in **chapter 4** [19].

Laparoscopic techniques and hospital costs

During the last two decades, laparoscopic resection has developed as a commonly accepted surgical procedure for colorectal cancer. However, there have been questions regarding the cost-efficacy, mostly because of prolonged operation time and higher costs of operation materials (e.g. disposables) [20,21]. The DVBHC-database was used to compare actual 90-day hospital costs between elective open and laparoscopic colon and rectal cancer resection. Analyses were performed by using sub-group analyses based on operative risk and reported in **chapter 5** [22].

The Jeroen Bosch Hospital (Den Bosch, The Netherlands) is one of the Dutch pioneers in performing single port laparoscopy (SPL) for colorectal cancer and Jeroen Bosch Hospital’s surgeons started using SPL in 2011. Since SPL is a relatively new technique, little is known about is effect on hospital costs. In **chapter 6** [23] we describe clinical and financial outcomes between SPL and conventional laparoscopy for colorectal cancer performed at the Jeroen Bosch Hospital.

High-risk patients and hospital costs

Frail patients are at high risk for developing complications after major surgery and therefore detailed performance information of those patients is of interest for healthcare providers. Moreover, due to increasing health care costs, discussion regarding increased hospital costs when operating high-risk and/or frail patients is rising. To facilitate this discussion, we analyzed hospital costs of two specific sub-groups suffering from high complication rates. Firstly, the impact of obesity on hospital costs is reported in **chapter 7** [24]. Since evidence from general surgery suggest that there seems to be a so-called "obesity paradox" (lower mortality rates after surgery for pre-obese and mildly obese patients as compared to normal weight patients) [25], this was also investigated in this study. Secondly, hospital costs of the oldest old colorectal cancer patients (age 85 and older) were analyzed and the results are reported in **chapter 8** [26].

Reimbursement and quality improvement

The current reimbursement system in the Netherlands is not contributing to any improvement in value of care. At the moment, colorectal cancer reimbursement is partly based on length of hospital stay (with a cut-off at day 28). Although not very likely because of the integrity of healthcare providers, it might even provide a perverse stimulant (e.g., complications will result in longer hospital stay and therefore result in a higher reimbursement). As suggested by Michael Porter, reimbursement in healthcare should be tied to overall care for the patient and should include severity adjustments and (long-term) care guarantees that hold the provider responsible for avoidable complications [27]. Based on the subgroup analyses showed in **chapter 5** [22], an alternative reimbursement system for colorectal cancer surgery in the Netherlands is suggested in **chapter 9** [28].

REFERENCES

1. Björnberg A. *Euro Health Consumer Index 2015.* 2015. ISBN 978-91-980687-5-7.
2. OECD. Health at a Glance: Europe 2014. 2014; http://www.oecd.org/health/health-at-a-glance-europe-23056088.htm. Accessed 25-09-2016.
3. *'De zorg: hoeveel extra is het ons waard?'.* The Dutch Ministry of Health Welfare and Sport; 2012-12-06 2012.
4. Porter ME, Lee TH. The Strategy That Will Fix Health Care. *Harvard business review.* 2013;91(10).
5. Larsson S, Lawyer P, Garellick G, Lindahl B, Lundstrom M. Use of 13 disease registries in 5 countries demonstrates the potential to use outcome data to improve health care's value. *Health Aff (Millwood).* 2012;31(1):220-227.
6. Khuri SF, Daley J, Henderson W, et al. The Department of Veterans Affairs' NSQIP: the first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care. National VA Surgical Quality Improvement Program. *Annals of surgery.* 1998;228(4):491-507.
7. Lothian and Borders large bowel cancer project: immediate outcome after surgery. The consultant surgeons and pathologists of the Lothian and Borders Health Boards. *The British journal of surgery.* 1995;82(7):888-890.
8. Van Leersum NJ, Snijders HS, Henneman D, et al. The Dutch surgical colorectal audit. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2013;39(10):1063-1070.
9. DICA. *DSCA jaarrapportage 2014* 2015.
10. Dreyer NA, Garner S. Registries for robust evidence. *Jama.* 2009;302(7):790-791.
11. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2016. *CA Cancer J Clin.* 2016;66(1):7-30.
12. Ferlay J, Steliarova-Foucher E, Lortet-Tieulent J, et al. Cancer incidence and mortality patterns in Europe: estimates for 40 countries in 2012. *Eur J Cancer.* 2013;49(6):1374-1403.
13. DICA. *DSCA jaarrapportage 2015.* 2016.
14. Schilling PL, Dimick JB, Birkmeyer JD. Prioritizing quality improvement in general surgery. *Journal of the American College of Surgeons.* 2008;207(5):698-704.
15. Performation. http://www.performation.com.
16. Porter ME, Lee TH. The Strategy That Will Fix Health Care. *Harvard business review.* 2013;91(12):24-24.
17. Govaert JA, van Bommel AC, van Dijk WA, van Leersum NJ, Tollenaar RA, Wouters MW. Reducing healthcare costs facilitated by surgical auditing: a systematic review. *World journal of surgery.* 2015;39(7):1672-1680.
18. Govaert JA, van Dijk WA, Fiocco M, et al. Nationwide Outcomes Measurement in Colorectal Cancer Surgery: Improving Quality and Reducing Costs. *Journal of the American College of Surgeons.* 2016;222(1):19-29 e12.
19. Govaert JA, Fiocco M, van Dijk WA, et al. Costs of complications after colorectal cancer surgery in the Netherlands: Building the business case for hospitals. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2015;41(8):1059-1067.

20. van der Pas MH, Haglind E, Cuesta MA, et al. Laparoscopic versus open surgery for rectal cancer (COLOR II): short-term outcomes of a randomised, phase 3 trial. *Lancet Oncol.* 2013;14(3):210-218.
21. Braga M, Vignali A, Zuliani W, Frasson M, Di Serio C, Di Carlo V. Laparoscopic versus open colorectal surgery: cost-benefit analysis in a single-center randomized trial. *Annals of surgery.* 2005;242(6):890-895, discussion 895-896.
22. Govaert JA, Fiocco M, van Dijk WA, et al. Multicenter Stratified Comparison of Hospital Costs Between Laparoscopic and Open Colorectal Cancer Resections: Influence of Tumor Location and Operative Risk. *Annals of surgery.* 2016.
23. van der Linden YT, Govaert JA, Fiocco M, van Dijk WA, Lips DJ, Prins HA. Single center cost analysis of single-port and conventional laparoscopic surgical treatment in colorectal malignant diseases. *International journal of colorectal disease.* 2016.
24. Govaert JA, Lijftogt N, van Dijk WA, et al. Colorectal cancer surgery for obese patients: Financial and clinical outcomes of a Dutch population-based registry. *Journal of surgical oncology.* 2016;113(5):489-495.
25. Mullen JT, Moorman DW, Davenport DL. The obesity paradox: body mass index and outcomes in patients undergoing nonbariatric general surgery. *Annals of surgery.* 2009;250(1):166-172.
26. Govaert JA, Govaert MJ, Fiocco M, et al. Hospital costs of colorectal cancer surgery for the oldest old: A Dutch population-based study. *Journal of surgical oncology.* 2016.
27. Porter ME, Kaplan RS. How to pay for health care. *Harvard business review.* 2016;94(7/8).
28. Govaert JA, van Dijk WA, Wouters WM. Gedifferentieerd belonen: een instrument naar verdere kwaliteitsverbetering en kostenreductie in de gezondheidszorg? *Nederlands tijdschrift voor geneeskunde.* 2017 (accepted).

CHAPTER 2

J.A. Govaert *

A.C.M. van Bommel *

W.A. van Dijk

N.J. van Leersum

R.A.E.M. Tollenaar

M.W.J.M. Wouters

* J.A. Govaert and A.C.M. van Bommel contributed equally to this work

REDUCING HEALTHCARE COSTS FACILITATED BY SURGICAL AUDITING: A SYSTEMATIC REVIEW

World Journal of Surgery 2015

ABSTRACT

Background

Surgical auditing has been developed in order to benchmark and to facilitate quality improvement. The aim of this review is to determine if auditing combined with systematic feedback of information on process and outcomes of care results in lower costs of surgical care.

Method

A systematic search of published literature before 21-08-2013 was conducted in Pubmed, Embase, Web of Science, and Cochrane Library. Articles were selected if they met the inclusion criteria of describing a surgical audit with cost-evaluation.

Results

The systematic search resulted in 3608 papers. Six studies were identified as relevant, all showing a positive effect of surgical auditing on quality of healthcare and therefore cost savings was reported. Cost reductions ranging from $16 to $356 per patient were seen in audits evaluating general or vascular procedures. The highest potential cost reduction was described in a colorectal surgical audit (up to $1,986 per patient).

Conclusions

All six identified articles in this review describe a reduction in complications and thereby a reduction in costs due to surgical auditing. Surgical auditing may be of greater value when high-risk procedures are evaluated, since prevention of adverse events in these procedures might be of greater clinical and therefore of greater financial impact.

Implication of key findings

This systematic review shows that surgical auditing can function as a quality instrument and therefore as a tool to reduce costs. Since evidence is scarce so far, further studies should be performed to investigate if surgical auditing has positive effects

to turn the rising healthcare costs around. In the future, incorporating (actual) cost analyses and patient-related outcome measures would increase the audits' value and provide a complete overview of the value of healthcare.

INTRODUCTION

By acknowledging the importance of reliable and valid quality information in healthcare, in the last decades, surgical audits have been initiated in several countries. Surgical auditing is a quality instrument that collects detailed clinical data from health care providers, which is used to improve quality of care by timely feedback to clinicians about their (case-mix adjusted) results and facilitate benchmarking between participating hospitals [1]. Moreover, surgical auditing provide useful information of patients usually not eligible for clinical trials and are therefore of great value for all day practice [2]. With Sweden as a pioneer [3], countries like the United Kingdom (Lothian and Borders large bowel cancer project) [4], the United States (National Surgical Quality Improvement Program) [5] and the Netherlands (Dutch Surgical Colorectal Audit) [6] developed and implemented nationwide surgical audits as well.

As raised by Michael E. Porter, the overall goal in health care should be maximizing value for patients. Value is defined as 'the health outcomes achieved that matter to patients, relative to costs of achieving those outcomes' [7,8]. One of the six components of Porter's Value Based Health Care is 'measurement of outcomes and costs for every patient'. As emphasized by Larsson et al. [3], measurement of outcomes by surgical audits perfectly facilitates this process of improving healthcare. With auditing, results are systematically measured and therefore might improve outcomes [9,10].

Despite its important societal and economical position, the healthcare industry has been lagging behind regarding the availability of key data on process and outcomes of care, when compared to other industries where product evaluation is standardly embedded in the production process. Most often, focus is on patient care and quality of care instead of costs and cost reduction. Especially in the era of rapidly increasing healthcare costs, evaluation of treatments and its costs might be highly prioritized in order to reduce costs and provide good value healthcare. In the literature so far, many articles have been published describing a relationship between surgical auditing and quality improvement. However, surgical auditing in combination with cost evaluation is described less often. Therefore, this systematic review aims to evaluate the effects of surgical auditing on hospital costs.

METHODS

Search strategy

A systematic search of published literature before 21-08-2013 was conducted in Pubmed, Embase, Web of Science, and Cochrane Library. A specialized librarian of our institution constructed the search. No MeSH terms for studies related to 'audit', as in quality instrument that collects detailed clinical data from health care providers and 'costs', as in financial expenditure were available. Therefore, the search strategy included a variety of search terms describing 'audit' and 'costs' in order to prevent exclusion of relevant articles. Search terms on auditing (e.g., 'audit', 'outcome and process assessment', 'NSQIP', 'benchmark', 'outcome registry') and search terms on costs (e.g., 'finance', 'economic', 'costs') were combined with search terms on surgery (e.g., 'surgery', 'surgeon'), see appendix 1 for the complete search. Meeting abstracts, duplicates and non-English-language studies were excluded.

Selection of studies

Three authors (J. G., A. v. B., M. W.) defined the inclusion criteria. Articles were included if they met the following criteria: (1) at least one process or outcome indicator was measured or an audit was described which had been established to monitor and evaluate quality of care, (2) the indicator or audit focused on patient care within the surgical department, (3) the indicator or surgical audit itself described cost evaluation over time. Two investigators (J. G., A. v. B.) independently reviewed each title and, if applicable, the abstract was reviewed. The articles included after screening title and abstract, were evaluated by reading the complete manuscript. Disagreements on selection of a study were solved by deliberation between the two investigators or by consulting a third reviewer (M.

W.). For additional relevant articles, reference lists and citations of the included studies were verified.

Calculations

All costs are stated in U.S. dollars and inflated to 2013 using the Consumer Price Index[11], unless otherwise described. In the case of foreign currency the currency was first converted to U.S. dollars using the yearly average currency exchanges rate [12]. If applicable, the effect on costs per patient due to surgical auditing was calculated by dividing the amount of total savings by the number of patients listed in the study.

RESULTS

Search results

The systematic search revealed a total of 5,505 citations. After excluding duplicates and meeting abstracts, 3,608 articles were eligible for evaluation. Main reason for exclusion criteria was studies revealing clinical pathways or population-based studies instead of audits with regular feedback and benchmark. Furthermore, studies not showing any information on costs were excluded.

Twenty-nine articles met the inclusion criteria on title and abstract. However, 16 articles were excluded after reading the manuscript because no surgical audit was described (inclusion criterion one). Although all remaining 13 articles described an audit in a surgical setting (inclusion criterion two), another seven articles were excluded since they did not show any data on cost reduction over time (inclusion criterion three). Some of those articles theorize about cost reduction or costs effectiveness due to surgical auditing, but do not describe actual financial calculations [10,13-15].

A total of six articles met the predefined inclusion criteria [16-21]. The reference lists of these six studies revealed no new articles. The study selection is shown in Figure 1.

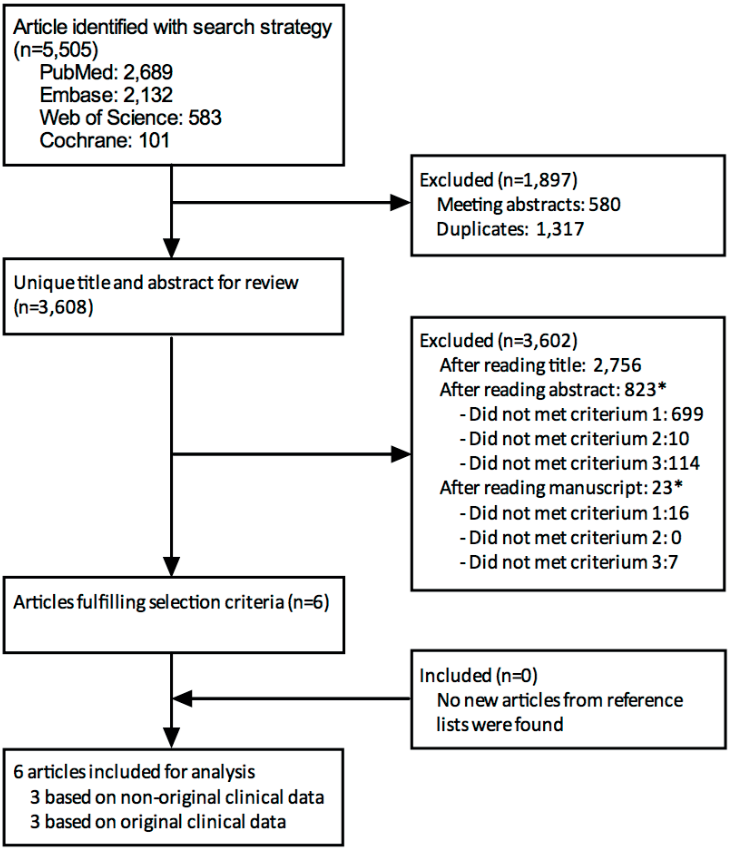


Figure 1. Selection process
The used strategy is outlined in appendix 1.

Auditing and costs

All six studies describe a relationship between surgical auditing and cost reduction. However, three studies based their analyses on non-original clinical data [19-21] and were therefore analyzed separately (Table 1).

Table 1. Included articles using non-original clinical data

First author	**Englesbe**	**Gordon**	**Larsson**
Year of publication	**2007**	**2010**	**2013**
Audit/ source	Michigan Surgical Quality Consortium*	Literature review 'complications colorectal cancer surgery' and 'effectiveness of surgical audits'	Swedish Hip Arthroplasty Register
Procedures analysed	General and vascular surgery	Colorectal cancer surgery	Hip surgery
Setting	15 United States hospitals	Australian hospitals	Swedish hospitals
Start Audit	2005	Not applicable	1979
Estimated clinical outcome**	3% complication reduction based on earlier published data	50% reduction of adverse events based on literature	Reduction of 750 hip revisions a year as compared to U.S. setting
Estimated financial outcome**	$936,667 (2007: $833,333) per year for 15 hospitals***	$24 million (2009: AU$ 30,3 million) per year for all Australian hospitals	$14.5 million (2011: $14 million) per year for all Swedish hospitals
Average patient savings	$18 (2007: $16)***	$1,986 (2009: AU$ 2,436)	Not described

* Clinical data retrieved from American College of Surgeons - National Surgical Quality Improvement Program, ** outcomes are estimations since these articles did not use original data, ***analysis based on financial data in article.

Non-original clinical data

Englesbe et al.[20] described the potential for payers to participate in quality improvement programs by supporting 80 % of data collection costs and all of the coordinating center costs. If a reduction of surgical complications (general and vascular surgery) by 3 % per year was established by the Michigan Surgical Quality Collaborative (MSQC); the payer would save $2.81 million (2007: $2.5 million) on the program after 3 years. Gordon et al. [21] estimated the potential cost savings for colorectal surgery in Australian hospitals. Savings were attributed to a surgical self-audit system by combining existing literature on colorectal cancer surgery complications and effectiveness of surgical audit with financial data. A potential of $24.7 million (2009: AU $30.3 million) could be saved for colorectal cancer surgery in Australian hospitals each year by implementing surgical self-auditing. The third identified article by Larsson et al. [19] analyzed the potential of disease registries to improve healthcare in five different countries. Only for the Swedish Hip Arthroplasty Register financial analyses were performed. Based on registry data (no details specified), an estimation was made that Sweden avoided 7,500 hip revisions between 2000 and 2009, if Sweden's revision burden had been as high as that of the United States in the same period. Given costs of $19,159 (2011: $18,500) per revision (financial analyses not further specified) Larsson et al. estimated that $14,499 million (2009: $14 million) could be avoided per year in revision costs for hip surgery.

Original clinical data

The other three articles, based on original data, were published in the last 4 years and retrieved their clinical data from the American College of Surgeons—National Quality Improvement Program (ACS-NSQIP) (Table 2) [16-18].

For the financial analyses, one study referred to another article [20] describing a standardized price per complication [16]. Another study used standardized complication prices based on the ACS-NSQIP Return Of Investment (ROI) calculator [18]. The third article used 'real costs' using the hospital accounting database [17].

The article from Henke et al.[16] was from the same study group as Englesbe et al.[20]. Patient variables of vascular procedures (provided by ACS-NSQIP) for the original 16 hospitals of the MSQC were used. Costs of one major complication were derived from the earlier article by Englesbe et al. [20] having a fixed price of $8,287. Between the first two years and the third year, a 2 % reduction in complication rate was achieved, leading to an average cost reduction of $186 (2008: $172) per patient. Hollenbeak et al.[17] described an improvement in cost-effectiveness with longer duration in participation in the auditing program, for both general and vascular procedures in an academic setting. Where they report a cost of $27,658 (2009: $25,471) to avoid one postoperative event 1 year after initiation of the program, these expenditures declined to 28.7 % ($7,947 (2009: $7,319)) of the initial costs 2 years after the initiation. By multiplying the savings of avoiding one postoperative event in their studied population ($9829 (2009: $9,052)) with the reduction in postoperative events (3.63 %), the program saved an average of $356 (2009: $328)

Table 2. Included articles using original clinical data

Article characteristics				
First author		Henke	Hollenbeak	Guillamondegui
Year of publication		2010	2011	2012
Audit characteristics				
Name		MSQC*	ACS-NSQIP	TSQC*
Procedures analysed		Vascular surgeries	General and vascular surgeries	General and vascular surgeries
Setting		16 U.S. hospitals	1 U.S. academic hospital	10 U.S. hospitals
Start Audit		2005	Jul. 2007	May 2008
Control period		Apr. 2005 - Mar. 2007	Study 1: Jul. 2007 - Dec. 2007 Study 2: Jul. 2007 - Jun. 2008	Jan. 2009 - Dec. 2009
Audit period		Apr. 2007 - Mar. 2008	Study 1: Jul. 2008 - Dec. 2008 Study 2: Jul. 2008 - Jun. 2009	Jan. 2010 - Dec. 2010
Summary QI program		Timely feedback of data and comparison between institutions	Not specified (start of QI program in July 2008)	Sharing surgical process and out-come data between hospitals
Clinical characteristics				
Study size	Control	2,453 patients	Study 1: 699 patients Study 2: 1,230 patients	14,205 patients
	Audit	3,409 patients	Study 1: 522 patients Study 2: 992 patients	14,901 patients
Main clinical outcomes		2% decrease in overall morbidity.	Not described	Significant reduction in: SSI, >48 ventilator hours, graft/host/flap failure, RF, wound disruption
Financial characteristics				
Financial source		Hospital accounting database	Hospital accounting database	ACS-NSQIP ROI calculator
Inclusion program costs		No	Yes (2009: $138,821 a year)	Yes (ROI calculator)
Financial analyses		Extrapolated cost savings from complication rates (earlier study)	Costs-to-charges methodology, audit group included NSQIP fee	Complication rate difference multiplied by complication costs
Average patient savings		$186 (2008: $172)	$356 (2009: $328)**	$238 (2009: $219)**

Abbreviations: MSQC= Michigan Surgical Quality Consortium, ACS-NSQIP= American College of Surgeons - National Surgical Quality Improvement Program, TSQC= Tennessee Surgical Quality Consortium, U.S.= United States, QI= quality improvement, ROI= Return On Investment, SSI= surgical side infection, RF= renal failure.
* Clinical data retrieved from ACS-NSQIP, **calculation based on financial data in article.

per patient. Costs of the audit itself [$150,740 (2009: $138,821)], for example the NSQIP license fee and salary for a clinical nurse reviewer, were taken into account. The study of Guillamondegui et al. [18] described improved clinical outcomes between the first and second year after implementation of a regional surgical quality collaborative of ten hospitals (the Tennessee Surgical Quality Collaborative). The reduction in complications of general and vascular procedures was translated to costs with the use of the ACS-NSQIP ROI calculator. The ROI calculator calculates costs of complications and includes costs for enrollment and participation in NSQIP. Net cost avoided between the first and second year was $2,276,911 (2011: $2,198,543) per 10,000 surgical cases. The authors outline that although the mechanisms for these changes are likely multifactorial, the Tennessee Surgical Quality Collaborative established communication, process improvement, and discussion among the members.

DISCUSSION

In this systematic review, a relationship between surgical auditing and reduced healthcare costs was identified. Though frequently assumed in the literature, only six articles actually described this relationship. All identified studies suggest that besides quality improvement, surgical auditing has the potential to reduce in-hospital costs.

With the continuous rise of healthcare costs, healthcare providers, insurance companies, governments, and patients demand for information and transparency on performance of hospitals. Surgical audits facilitate this process and, most important, surgical auditing might lead to improved outcomes for patients. Whether this involves orthopedic surgery [22], colorectal surgery [6], vascular surgery [16] or general surgery [9,10,17,18], all show an association with improved clinical outcome. Because of the cost- and time-consuming exercise of data collection [23], the use of surgical auditing as a quality instrument will catalyze only when it proves to be cost-effective. Four of the identified articles [17,18,20,21] incorporated costs of the audit itself in their calculations and therefore analyzed the actual cost-effectiveness of surgical audits.

These four studies showed larger reduction in costs (due to quality improvement) compared to the audit-participation-costs, and therefore overall cost reduction was established.
Notable variation was seen in the amount of cost reduction per patient between the reported studies. Four articles using data from the ACS-NSQIP [16-18,20] described savings in a small spectrum ranging from $18 (2007: $16) [20] to $356 (2009: $328) [17] per patient. All these studies were based on vascular or general surgical procedures, however separate financial analyses for low- or high-risk procedures were not made. Gordon et al. [21] described the highest (potential) cost reduction, reaching up to $1,986 (2009 AU$2,436) per patient. However the reported reduction of complications by 50 % accomplished with 'self-auditing', might overestimate clinical reality [6]. A factor that attributed to the high reduction in costs in this study might be the selection of colorectal cancer patients. In high-risk procedures, like colorectal cancer resections, the prevention of adverse events, such as anastomotic leakage, might be of greater clinical [24] and financial impact.
Remarkable, Hollenbeak et al. [17] found further cost reduction when audits were used for a longer period. This is also seen in the study by van Leersum et al. describing the first three years of the Dutch Surgical Colorectal Audit (DSCA). Between the first and the second year of the DSCA, the improvement in quality seemed to be less distinct then between the second and third year [6]. Hollenbeak et al.[17] explained the improved cost effectiveness after a longer duration of participation by the later onset of the effect of improvement activities. Whether results further improve with even longer duration of a surgical audit should be addressed in future studies.
The exact mechanism of cost reduction by surgical auditing is sometimes hard to identify. As seen in the literature, occurrence of complications goes hand in hand with increased hospital costs [25,26], for example due to prolonged length of hospital stay, prolonged intensive care stay and increased reoperations. The cornerstone of surgical auditing is collecting performance data and providing (benchmarked) feedback tot surgeons, leading to identification of existing problems in the care process. Knowledge of performances can facilitate quality improvement of the participating hospitals, resulting in fewer complications [6] and therefore fewer costs.

A note of caution should be made in ascribing improved quality of care (or cost reduction) to surgical auditing, since possible occurrences of secular trends not registered in the audit could influence outcomes as well [17,27]. Also continuous development of new surgical techniques might have beneficial effect on its own. For example, the development of laparoscopic techniques may result in lower complication rates, shorter length of hospital stay, and therefore lower costs [28]. Quality improvements initiatives in individual hospitals (introduced independently from the surgical audit) might have led to overestimation of auditing results. Also participation in a registry might have some kind of Hawthorne-effect as addressed by Guillamondegui et al. [18]. Nevertheless, without availability of key data on outcomes, health care organizations are flying blind in deciding what should be targets for quality improvement initiatives or in deciding which 'peer-hospitals' could serve as best practice hospitals, and therefore underlying the need of audits.

An opportunity to improve insight in the value of healthcare is the introduction of more accurate cost calculations when evaluating care processes. Hollenbeak et al. [17] analyzed costs for each admission, though insights in these calculations were not given. Also, the use of the ACS NSQIP ROI calculator [18] or Diagnose Related Groups (DRG) instrument [21] is a proxy of costs of complications, and actual costs undoubtedly vary between hospitals. Henke et al. [16], Englesbe et al. [20] and Larsson et al. [19] used a fixed price for complications by referring to earlier published articles but detailed descriptions were not given.

As suggested by Porter et al., calculating true medical costs would give a more accurate financial perspective [7] and allows to determine the value of care. and allows one to determine the value of care. To do so, healthcare providers must measure costs at medical condition level and for the complete cycle of care. Therefore, actual costs should be used instead of declaration data. Calculating actual costs requires understanding of the resources used in patient's care, including staff, equipment, medication, facilities, and support costs (IT, maintenance). The methodology Porter recommends to calculate the costs is time-driven activity-based costing (TD-ABC) [29,30]: actual costs are calculated by identifying all clinical services in a healthcare organization and assigning both direct and indirect costs to each clinical service. Using time estimates, or actual data when available (for example in the operation room), for each service allows to specifically allocate all costs. This methodology is not commonly used in healthcare, and therefore not mentioned in literature. Articles describing an accurate translation of resource utilization into costs are scarce [31,32]. In general, cost-based studies often use DRGs [21] or insurance claim data [33,34] to indicate expenditures. These methods do not seem to provide an accurate economic perspective either, since DRGs do not represent 'real costs' but mainly depend on the classification system used [35,36]. Moreover, since no uniformity or transparency of costs registration in various hospitals exists, most of these 'real cost' studies are limited to single-center settings [17,31,32]. If used in a multi-center setting, these costs are often retrieved from a single hospital's accounting system and extrapolated to the other participating institutions [37].

Limitations

No specific MeSH terms related to 'audit' and 'costs' were used. Using these two terms would result in a broad spectrum of articles describing audit as in 'any retrospective database' or costs as in 'non-financial costs'. Restriction of the search (e.g., using 'financial costs' instead of'costs') consequently increases the potential of missing relevant literature. Therefore, the search strategy included a variety of search terms describing 'audit' and 'costs' (see appendix 1). This resulted in many articles describing clinical pathways or population-based studies without a feedback mechanism, which were excluded for this reason (exclusion criterium 1). Because we did not find any new related articles by checking references and citations of the six included studies, the search terms seem to be adequate. Though we used broad search terms, we only identified six articles as relevant. The three studies using original clinical data retrieved their data from 27 hospitals. Therefore, caution should be taken in generalization of our findings since results found in these hospitals may not be representative at other institutions. Finally, a major limitation of the investigated studies is the potential occurrence of publication and selection bias. Studies showing negative outcomes of surgical auditing might less likely to be submitted by the authors. Also the included studies were not designed as randomized controlled trials, therefore unattended selection bias might be introduced since the interventions (the audits themselves) were not allocated randomly to patients. The results of this systematic review should be interpreted having this limitation in mind.

Future perspectives

We were surprised by the lack of evidence for cost evaluation of surgical auditing. As addressed by Porter, measuring clinical outcomes and costs at patient level should be embedded in the quality improvement process of healthcare [7]. In addition, the authors believe that combining clinical outcomes with patient reported outcome measures (PROMs) would provide an even stronger tool. Benchmarking hospitals on quality, costs, and PROMs could identify 'best practices' on all three dimensions, which will lead to higher quality of care with the use of fewer resources and less costs.

Although we only identified articles focused on hospital related costs, registries that cover the complete patient cycle should provide better insights. Long-term complications can be identified which might cover 'hidden' long-term costs. For example, in colorectal cancer surgery, the creation of a defunctioning stoma shortens length of hospital stay during the initial operation and lowers short-term complications [38]. However, next to the impact on quality of life a stoma has, it also has serious long-term financial implications. Patients have a life time need for colostomy pouches and a constant risk for long-term complications [39] which are seen in up to fifty percent of the patients within ten year follow up [40]. Increasing quality and reducing costs is the fundamental base of 'value based health care' [7]. Therefore, covering short- as well as long-term outcomes should be aimed for all health care evaluations. While surgical auditing has become more integrated in common practice, its effectiveness on costs needs to be evaluated as well, and perhaps costs evaluation has to be incorporated in the feedback mechanisms of the audit.

CONCLUSIONS

Ideally, the overall quality improvement related to surgical auditing should be judged with the assessment of its costs. In literature, only six articles [16-21] have been published so far, describing cost reduction due to auditing. Potential higher cost reduction is seen when the surgical audit is focused on high-risk procedures only, such as colorectal cancer surgery. Auditing could perfectly facilitate the decision- making process for reducing costs, as addressed by Porter et al. and Larsson et al.[19,41]. Nonetheless, further studies should be performed to confirm whether surgical auditing has sustainable (long-term) effects in confining the rise in healthcare costs.

RECOMMENDATIONS

In future, widespread introduction and continuous use of surgical auditing is required to evaluate and improve quality of medical care for patients. The main focus should be evaluation of high-risk procedures since prevention of adverse events in these procedures will have greater clinical and financial impact compared to low-risk procedures. Moreover, when financial outcomes are incorporated in the audit, calculating those financial outcomes should be based on actual costs, for example using time-driven activity-based costing. In the future, covering the complete cycle of care and incorporating cost analyses and patient-related outcome measures would increase the audits' value and provide a complete overview of the value of healthcare. Further studies describing the audit's value should include all of the above-mentioned elements, in order to provide more robust evidence for further implementation of auditing.

ACKNOWLEDGEMENT

We would like to thank J.W. Schoones (specialized librarian, Leiden University Medical Center, Leiden, The Netherlands) for his assistance with the literature search.

REFERENCES

1. van Gijn W, Wouters MW, Peeters KC, van de Velde CJ. Nationwide outcome registrations to improve quality of care in rectal surgery. An initiative of the European Society of Surgical Oncology. *Journal of surgical oncology.* 2009;99(8):491-496.
2. Dreyer NA, Garner S. Registries for robust evidence. *Jama.* 2009;302(7):790-791.
3. Stefan Larsson PL, Martin B. Silverstein. From Concept to Reality. Putting Value-Based Health Care into Practice in Sweden. *Boston Consulting Group.* 2010.
4. Lothian and Borders large bowel cancer project: immediate outcome after surgery. The consultant surgeons and pathologists of the Lothian and Borders Health Boards. *The British journal of surgery.* 1995;82(7):888-890.
5. Khuri SF, Daley J, Henderson W, et al. The Department of Veterans Affairs' NSQIP: the first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care. National VA Surgical Quality Improvement Program. *Annals of surgery.* 1998;228(4):491-507.
6. Van Leersum NJ, Snijders HS, Henneman D, et al. The Dutch surgical colorectal audit. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2013;39(10):1063-1070.
7. Porter ME, Lee TH. The Strategy That Will Fix Health Care. *Harvard business review.* 2013;91(10).
8. Michael E. Porter ET. Redefining Health Care: Creating Value-Based Competition on Results *Harvard Business Press.* 2006.
9. Khuri SF. The NSQIP: a new frontier in surgery. *Surgery.* 2005;138(5):837-843.
10. Hall BL, Hamilton BH, Richards K, Bilimoria KY, Cohen ME, Ko CY. Does surgical quality improve in the American College of Surgeons National Surgical Quality Improvement Program: an evaluation of all participating hospitals. *Annals of surgery.* 2009;250(3):363-376.
11. United States Department of Labor, Bureau of Labor Statistics. http://www.bls.gov.
12. United States Department of the Treasury, Internal Revenue Service. http://www.irs.gov.
13. Stachler RJ, Yaremchuk K, Ritz J. Preliminary NSQIP results: a tool for quality improvement. *Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery.* 2010;143(1):26-30, 30 e21-23.
14. Paxton EW, Inacio MC, Kiley ML. The Kaiser Permanente implant registries: effect on patient safety, quality improvement, cost effectiveness, and research opportunities. *Perm J.* 2012;16(2):36-44.
15. Paxton EW, Kiley ML, Love R, Barber TC, Funahashi TT, Inacio MC. Kaiser Permanente implant registries benefit patient safety, quality improvement, cost-effectiveness. *Joint Commission journal on quality and patient safety / Joint Commission Resources.* 2013;39(6):246-252.
16. Henke PK, Kubus J, Englesbe MJ, Harbaugh C, Campbell DA. A statewide consortium of surgical care: a longitudinal investigation of vascular operative procedures at 16 hospitals. *Surgery.* 2010;148(4):883-889; discussion 889-892.
17. Hollenbeak CS, Boltz MM, Wang L, et al. Cost-effectiveness of the National Surgical Quality Improvement Program. *Annals of surgery.* 2011;254(4):619-624.
18. Guillamondegui OD, Gunter OL, Hines L, et al. Using the National Surgical Quality Improvement Program and the Tennessee Surgical Quality Collaborative to improve surgical

outcomes. *Journal of the American College of Surgeons.* 2012;214(4):709-714; discussion 714-706.

19. Larsson S, Lawyer P, Garellick G, Lindahl B, Lundstrom M. Use of 13 disease registries in 5 countries demonstrates the potential to use outcome data to improve health care's value. *Health Aff (Millwood).* 2012;31(1):220-227.
20. Englesbe MJ, Dimick JB, Sonnenday CJ, Share DA, Campbell DA, Jr. The Michigan surgical quality collaborative: will a statewide quality improvement initiative pay for itself? *Annals of surgery.* 2007;246(6):1100-1103.
21. Gordon LG, Obermair A. Potential hospital cost-savings attributed to improvements in outcomes for colorectal cancer surgery following self-audit. *BMC surgery.* 2010;10:4.
22. Skutek M, Bourne RB, MacDonald SJ. International epidemiology of revision THR. *Curr Orthopaed.* 2006;20(3):157-161.
23. Hammermeister K. The National Surgical Quality Improvement Program: learning from the past and moving to the future. *American journal of surgery.* 2009;198(5 Suppl):S69-73.
24. Schilling PL, Dimick JB, Birkmeyer JD. Prioritizing quality improvement in general surgery. *Journal of the American College of Surgeons.* 2008;207(5):698-704.
25. Vonlanthen R, Slankamenac K, Breitenstein S, et al. The impact of complications on costs of major surgical procedures: a cost analysis of 1200 patients. *Annals of surgery.* 2011;254(6):907-913.
26. Dimick JB, Chen SL, Taheri PA, Henderson WG, Khuri SF, Campbell DA, Jr. Hospital costs associated with surgical complications: a report from the private-sector National Surgical Quality Improvement Program. *Journal of the American College of Surgeons.* 2004;199(4):531-537.
27. van der Geest LG, Krijnen P, Wouters MW, et al. Improved guideline compliance after a 3-year audit of multidisciplinary colorectal cancer care in the western part of the Netherlands. *Journal of surgical oncology.* 2012;106(1):1-9.
28. Delaney CP, Kiran RP, Senagore AJ, Brady K, Fazio VW. Case-matched comparison of clinical and financial outcome after laparoscopic or open colorectal surgery. *Annals of surgery.* 2003;238(1):67-72.
29. Kaplan RS, Porter ME. How to solve the cost crisis in health care. *Harvard business review.* 2011;89(9):46-52, 54, 56-61 passim.
30. Kaplan RS, Anderson SR. Time-driven activity-based costing. *Harvard business review.* 2004;82(11):131-138, 150.
31. Tapper R, Dixon L, Frampton C, Frizelle F. Impact of obesity on the cost of major colorectal surgery. *The British journal of surgery.* 2013;100(2):293-298.
32. Klarenbeek BR, Coupe VM, van der Peet DL, Cuesta MA. The cost effectiveness of elective laparoscopic sigmoid resection for symptomatic diverticular disease: financial outcome of the randomized control Sigma trial. *Surgical endoscopy.* 2011;25(3):776-783.
33. Wick EC, Hirose K, Shore AD, et al. Surgical site infections and cost in obese patients undergoing colorectal surgery. *Archives of surgery.* 2011;146(9):1068-1072.
34. Lawson EH, Hall BL, Louie R, et al. Association between occurrence of a postoperative complication and readmission: implications for quality improvement and cost savings. *Annals of surgery.* 2013;258(1):10-18.
35. Quentin W, Scheller-Kreinsen D, Geissler A, Busse R, Euro DRGg. Appendectomy and diagnosis-related groups (DRGs): patient classification and hospital reimbursement in 11

European countries. *Langenbeck's archives of surgery / Deutsche Gesellschaft fur Chirurgie.* 2012;397(2):317-326.

36. Scheller-Kreinsen D, Quentin W, Geissler A, Busse R, Euro DRGG. Breast cancer surgery and diagnosis-related groups (DRGs): patient classification and hospital reimbursement in 11 European countries. *Breast.* 2013;22(5):723-732.
37. Janson M, Bjorholt I, Carlsson P, et al. Randomized clinical trial of the costs of open and laparoscopic surgery for colonic cancer. *The British journal of surgery.* 2004;91(4):409-417.
38. Matthiessen P, Hallbook O, Rutegard J, Simert G, Sjodahl R. Defunctioning stoma reduces symptomatic anastomotic leakage after low anterior resection of the rectum for cancer: a randomized multicenter trial. *Annals of surgery.* 2007;246(2):207-214.
39. Harris DA, Egbeare D, Jones S, Benjamin H, Woodward A, Foster ME. Complications and mortality following stoma formation. *Annals of the Royal College of Surgeons of England.* 2005;87(6):427-431.
40. Nastro P, Knowles CH, McGrath A, Heyman B, Porrett TR, Lunniss PJ. Complications of intestinal stomas. *The British journal of surgery.* 2010;97(12):1885-1889.
41. Porter ME. What is value in health care? *The New England journal of medicine.* 2010;363(26):2477-2481.

APPENDIX

Appendix 1. Pubmed, Embase, Web of Science and Cochrane search terms.

PubMed:

Limits activated: English.

("finance"[TIAB] OR "finances"[TIAB] OR "financial"[TIAB] OR "economics"[TIAB] OR "economic"[TIAB] OR "economics"[Majr] OR (("costs"[TIAB] OR "cost"[TIAB]) AND ("reduction"[TIAB] OR "improvement"[TIAB] OR "health care"[TIAB] OR "healthcare"[TIAB] OR "hospital"[TIAB])) OR "euro"[TIAB] OR "dollar"[TIAB] OR "pound"[TIAB] OR "euros"[TIAB] OR "dollars"[TIAB] OR "pounds"[TIAB] OR "pound"[TIAB]OR €[tiab] OR $[tiab] OR £[tiab])

AND

("surgery"[Subheading] OR "Surgical Procedures, Operative"[Majr] OR "Surgery"[tiab] OR "Surgical"[tiab] OR "Surgeon"[tiab] OR "Surgery Department, Hospital"[Majr] OR "Specialties, Surgical"[Majr:noexp])

AND

("Outcome and Process Assessment (Health Care)"[Majr] OR "audits"[tw] OR "auditing"[tw] OR "audit"[tw] OR "Clinical Audit"[Mesh:noexp] OR "Medical Audit"[Mesh] OR "Outcome Assessment"[tiab] OR "Process Assessment"[tiab] OR "Quality Assurance, Health Care"[Majr] OR "Quality Assurance"[tiab] OR "Quality Management"[tiab] OR "Quality Assessment"[tiab] OR "benchmark"[tiab] OR "benchmarks"[tiab] OR "benchmarking"[tiab] OR "NSQIP"[text word] OR "National Surgical Quality Improvement Program"[text word] OR "outcome registry"[TIAB] OR "Outcome and Process Assessment"[TIAB] OR "Quality of Health Care"[TIAB] OR "Quality of Healthcare"[TIAB] OR "Quality Control"[Majr])

Similar searches were performed in Embase, Web of Science and Cochrane databases.

CHAPTER 3

J.A. Govaert
W.A. van Dijk
M. Fiocco
A.C. Scheffer
L. Gietelink
M.W.J.M. Wouters*
R.A.E.M. Tollenaar*

* M.W.J.M. Wouters and R.A.E.M. Tollenaar contributed equally to this work

NATIONWIDE OUTCOMES MEASUREMENT IN COLORECTAL CANCER SURGERY: IMPROVING QUALITY AND REDUCING COSTS

Journal of the American College of Surgeons 2016

On behalf of the Dutch Value Based Healthcare Study Group

B. Lamme, MD, PhD (Albert Schweitzer Ziekenhuis, Dordrecht); D.A. Hess MD, PhD (Antonius ziekenhuis, Sneek); H.J. Belgers, MD (Atrium-Orbis, Heerlen); O.R. Guicherit, MD, PhD (MCH-Bronovo, Den Haag); C. Rosman, MD, PhD (Canisius Wilhelmina Ziekenhuis, Nijmegen); Prof H.J.T. Rutten, MD, PhD (Catharina Hospital, Eindhoven/ Maastricht University Medical Hospital, Maastricht); F.N.L. Versluijs-Ossewaarde. MD (Diaconessenhuis, Meppel); E.S. Van der Zaag, MD, PhD (Gelre Ziekenhuizen, Apeldoorn); L.N.L. Tseng, MD (Groene Hart Ziekenhuis, Gouda); E.J.R. de Graaf, MD, PhD (IJsselland Hospital, Capelle aan den Ijssel); W.J. Vles, MD, PhD (Ikazia Ziekenhuis, Rotterdam); E.G.J.M. Pierik, MD, PhD (Isala Kliniek, Zwolle); H.A. Prins, MD, PhD (Jeroen Bosch Ziekenhuis, Den Bosch); P.H.M. Reemst, MD (Máxima Medisch Centrum, Veldhoven); E.C.J. Consten, MD, PhD (Meander Medisch Centrum, Amersfoort); S.A. Koopal, MD PhD (Medisch Centrum Leeuwarden, Leeuwarden); P.A. Neijenhuis, MD, ScS (Alrijne Ziekenhuis, Leiderdorp); G.H.H. Mannaerts, MD, PhD (Sint Franciscus Gasthuis, Rotterdam); A.B. Smits, MD (St. Antonius Ziekenhuis, Nieuwegein); D.H.C. Burger, MD (Elisabeth-Tweesteden Ziekenhuis, Tilburg); M.G.A. van IJken, MD, PhD (Van Weel-Bethesda Ziekenhuis, Dirksland); P. Poortman, MD, PhD (Waterlandziekenhuis, Purmerend); M.J.P.M. Govaert, MD (Westfriesgasthuis, Hoorn); W.A. Bleeker, MD, PhD (Wilhelmina Hospital Assen); F.C. Den Boer, MD, PhD (Zaans Medical Center); F. Wit, MD (Ziekenhuis Tjongerschans, Heerenveen); Ph. M. Kruyt, MD (Ziekenhuis Gelderse Vallei, Ede); A. Mearadji, MD, PhD (Bravis Ziekenhuis, Bergen op Zoom); J.T. Heikens, MD, PhD (Ziekenhuis Rivierenland, Tiel)

ABSTRACT

Background

Recent literature suggests that focus in health care should shift from reducing costs to improving quality; where quality of health care improves, cost reduction will follow. Our primary aim was to investigate whether improving the quality of surgical colorectal cancer care, by using a national quality improvement initiative, leads to a reduction of hospital costs.

Study design

This was a retrospective analysis of clinical and financial outcomes after colorectal cancer surgery in 29 Dutch hospitals (9,913 patients). Detailed clinical data were obtained from the 2010 to 2012 population-based Dutch Surgical Colorectal Audit. Patient-level costs were measured uniformly in all participating hospitals and based on time-driven, activity-based costing. Odds ratios (OR) and relative differences (RD) were risk adjusted for hospitals and differences in patient characteristics.

Results

Over 3 consecutive years, severe complications and mortality declined by 20% (risk-adjusted OR 0.739, 95% CI 0.653 to 0.836, $p < 0.001$), and 29% (risk-adjusted OR 0.757, 95% CI 0.571 to 1.003, $p = 0.05$), respectively. Simultaneously, costs during primary admission decreased 9% (risk-adjusted RD -7%, 95% CI -10% to -5%, $p < 0.001$) without an increase in costs within the first 90 days after discharge (RD -2%, 95% CI -10% to 6%, $p = 0.65$). An inverse relationship (at hospital level) between severe complication rate and hospital costs was identified ($R = 0.64$). Hospitals with increasing severe complication rates (between 2010 and 2012) were associated with increasing costs; hospitals with declining severe complication rates were associated with cost reduction.

Conclusions

This report presents evidence for simultaneous quality improvement and cost reduction. Participation in a nationwide quality improvement initiative with con-

tinuous quality measurement and benchmarked feedback reveals opportunities for targeted improvements, bringing the medical field forward in improving value of health care delivery. The focus of health care should shift to improving quality, which will catalyze costs savings as well.

INTRODUCTION

Although consistently ranked number one in the European Health Consumer Index since 2008 [1], the Dutch Health Care System is struggling with rising costs. As one of the most expensive healthcare systems in Europe, the expenditure rose to 13.2% of the gross domestic product in 2012 [2]. In the last decades, health care providers have sought for solutions to stop this ongoing rise of health care costs. In spite of the well-intended effort, such as enforcing clinical guidelines or focus on volume and profitability of services, results have been meager.

The cornerstone of potential cost reduction could be availability of key clinical data on processes and outcomes of care [3]. Despite the important societal and economic role the health care system fulfills, it still lags behind when it comes to standardized reporting processes. In the past, data to compare the performance of different health care providers were scarce. With Sweden as a pioneer, worldwide clinical registries (audits) have been initiated on a regional or national level, leading to demonstrable improvement in clinical outcomes and smaller variation between providers [4-7]. With the introduction of the Dutch Surgical Colorectal Audit (DSCA) in 2009 [8], robust quality information became available, enabling monitoring, evaluation, and improvement of surgical colorectal cancer care in the Netherlands. The DSCA dataset covers 3 aspects: case-mix variables (e.g., age, sex, and comorbidity) necessary for hospital comparison; process variables (e.g., wait times, multidisciplinary team meetings, complete colonoscopy); and outcomes of care (e.g., mortality, length of hospital stay, number of lymph nodes, and complications like anastomotic leakage, pneumonia, or reinterventions). Key performance indicators, accompanied by a national benchmark, are fed back to clinicians on a weekly basis. Since the introduction of the DSCA, postoperative morbidity and mortality have declined. Despite the substantial registration effort, this might have led to significant savings in costs [7].

To explore the effect of this nationwide quality improvement initiative on health care costs, we conducted a comprehensive multi-center study involving 29 Dutch hospitals, using detailed clinical data from the DSCA and financial data based on time-driven, activity-based costing [9]. The aim of this study was to analyze whether nationwide collection of key clinical data and benchmarked feedback on performance indicators for colorectal cancer care lead to a reduction of hospital costs. Moreover, by combining and examining both clinical and financial outcomes, we examined whether identification of best practice hospitals, providing high quality colorectal cancer care for relatively low costs, is feasible.

METHODS

Clinical data

The dataset was retrieved from the DSCA, a population-based database in which detailed patient, tumor, diagnostic, procedural, and outcomes data are registered for all patients in the Netherlands undergoing resection of a primary colorectal carcinoma. The DSCA dataset is based on evidence-based guidelines, and each participating hospital appoints a surgeon responsible for (supervising) the data registration in a secured web form. Data are retrieved directly from the hospital information system (e.g., date of birth, sex, and unique patient identification number) and by manual data collection (e.g., tumor and operation characteristics). Data validity is achieved in various ways: by providing direct feedback on missing or erroneous data during data entry through quality control tools that are built in the program, by providing feedback information on the number of patients and completeness of the data per hospital, and by yearly external validation of the total dataset. The dataset shows nearly 100% completeness on most items and high accuracy level on validation (97% in 2012) against the Netherlands Cancer Registry [7,8]. A detailed description of the DSCA has been published recently [7,10].

Financial data

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 up to 90 days after discharge (Q1). Information on resource use at patient level (e.g., laboratory orders, operation room time, or ward days, Supplemental Table 1) was extracted from the hospital information system from each participating hospital. For each hospital, translation of patient level resource use into costs was provided by Performation (formerly known as TRAG Performance Intelligence), a health care consultancy firm providing patient level costing and benchmarking products for more than 100 hospitals across Europe [11,12]. Costs were calculated using time-driven activity-based costing (TD-ABC) [9] which is an advanced method for understanding hospitals costs [13,14]. Cost price calculations were standardized by Performation, so uniformity in methodology existed between all participating hospitals. The most recent cost price model (2012) for each hospital was used for all 3 years (2010, 2011, and 2012) to avoid differences due to inflation or the different models themselves. Different activities are grouped into 8 categories, as shown in Supplemental Table 1. Specialists' fees, medication costs, and costs for dialyses were excluded because registration of these parameters was not uniform in the participating hospitals, making equal comparison impossible.

Inclusion criteria

Hospital selection (n = 29) was based on the availability of detailed cost-price information for 3 consecutive years (2010, 2011, and 2012). The participating hospitals represent approximately one-third of the colorectal cancer procedures performed annually in the Netherlands (Supplemental Table 2), and 21 hospitals (72%) have a surgical teaching program. Patients undergoing surgical resection for primary colorectal cancer between January 1, 2010 and December 31, 2012 had to be registered in the DSCA before December 1, 2013. Minimal data requirements to consider a patient eligible for matching with the financial dataset were information on tumor location, date of surgery, and mortality status (10,101 eligible patients).

Match

The unique patient identification number combined with hospital of admission was used to match patients registered in the DSCA to their information in the financial database, resulting in a match of 98.1% (9,913 patients). A total of 188 patients (1.9%) without a match were excluded from analyses.

Definitions

Primary outcomes measures for quality of health care were postoperative mortality, defined as in-hospital death or within 30-days after surgery, and severe complications, defined as complications occurring during admission or within 30 days after surgery and leading to mortality, reintervention (operative or percutaneous), or a prolonged hospital stay of 14 days or more. The primary financial measure was total cost (primary admission up to 90 days after discharge). Other outcomes were length of hospital stay (starting from day of operation = day 1), costs of primary admission, costs of Q1 (first 90 days after discharge), and costs of primary admission and Q1 by category (as mentioned in Supplemental Table 1).

Analysis

Chi-square test and One-way Anova were used to investigate differences between patients' characteristics in the 3 analyzed years (Table 1). Three separate analyses were performed in this study. Outcomes in the first 2 analyses were risk-adjusted where stated, because high-risk patients are not evenly distributed between hospitals[15]. All significant ($p < 0.10$) risks factors (listed in Table 1) in univariate logistic regressions for severe complications were included in the multivariate model. Patient characteristics associated with severe complications were sex, BMI (categorical), age (categorical), comorbidity (Charlson score) [16], American Society of Anesthesiologists classification (ASA), presence of double tumor, location of tumor, stage of tumor (TNM), preoperative radiotherapy, resection of distant metastases, and urgency of resection. Patient characteristics associated with mortality were BMI, age, comorbidity (Charlson score) [16], ASA classification, location of tumor, stage of tumor (TNM), preoperative radiotherapy, distant metastases, and urgency of resection. Because BMI had more than 5% missing values, they were coded as a separate category to include those patients in the statistical analysis. To model financial outcomes and severe complications, the same patient characteristics were used.

The first method investigated differences in clinical and financial outcomes between the 3 consecutive years (Figure 1 and 2). Differences in outcomes between 2010 and 2012 were shown as crude relative differences (RD). To investigate if differences between 2010 and 2012 were due to differences in patient characteristics or variability

Table 1. Patient, tumor and treatment characteristic of patients, stratified by year of operation

		Total	**2010**	**2011**	**2012**	
		N (%)	N (%)	N (%)	N (%)	*p*-value
Total		9 913	3 131	3 152	3 630	
BMI (mean)		26.1	26.0	26.2	26.1	*0.22*
Age (mean)		69.9	70.1	69.7	69.9	*0.39*
Charlson score	Charlson 0	5 309 (3.6)	1 688 (53.9)	1 646 (52.2)	1 975 (54.4)	
	Charlson 1	2 265 (22.8)	721 (23.0)	716 (22.7)	828 (22.8)	*0.20*
	Charlson 2+	2 339 (23.6)	722 (23.1)	790 (25.1)	827 (22.8)	
ASA score	I-II	7 468 (75.3)	2 376 (76.3)	2 372 (75.8)	2 720 (75.0)	
	III	2 239 (22.6)	681 (21.9)	712 (22.7)	846 (23.3)	*0.45*
	IV-V	164 (1.7)	59 (1.9)	46 (1.5)	59 (1.6)	
Double tumor	Yes	325 (3.3)	78 (2.5)	102 (3.2)	145 (4.0)	*0.002*
Tumor location	Right colon	3 186 (32.1)	1 036 (33.1)	960 (30.5)	1 190 (32.8)	
	Left colon	1 151 (11.6)	356 (11.4)	368 (11.7)	427 (11.8)	*0.04*
	Sigmoid	2 673 (27.0)	863 (27.6)	892 (28.3)	918 (25.3)	
	Rectum	2 903 (29.3)	876 (28.0)	932 (29.6)	1 095 (30.2)	
Tumor stage (TNM)	Stadium unknown	180 (1.8)	55 (1.8)	53 (1.7)	72 (2.0)	
	Stadium 0	169 (1.7)	13 (0.4)	70 (2.2)	86 (2.4)	
	Stadium 1	646 (6.5)	210 (6.8)	178 (5.7)	258 (7.1)	*<0.001*
	Stadium 2	2 077 (21.0)	669 (21.6)	677 (21.8)	731 (20.2)	
	Stadium 3	5 454 (55.0)	1 731 (55.8)	1 727 (55.5)	1 996 (55.1)	
	Stadium 4	1 312 (13.2)	425 (13.7)	407 (13.1)	480 (13.2)	
Preoperative RT	None	7 439 (75.0)	2 388 (76.3)	2 311 (73.3)	2 740 (75.5)	
	5 x 5 Gy	1 386 (14.0)	445 (14.2)	476 (15.1)	465 (12.8)	*0.002*
	60 Gy / else	1 088 (11.0)	298 (9.5)	365 (11.6)	425 (11.7)	
Distant metastases	Yes	1 038 (10.5)	333 (10.6)	346 (11.0)	359 (9.9)	*0.32*
Metastasectomy	Yes	290 (2.9)	63 (2.0)	114 (3.6)	113 (3.1)	*0.001*
Extended resections	Yes	845 (8.5)	273 (8.7)	264 (8.4)	308 (8.5)	*0.88*
Urgency of resection	Urgent	1 334 (13.5)	432 (13.8)	440 (14.0)	462 (12.7)	*0.26*
Other characteristics*						
Surgical approach	Laparoscopic	4 579 (46.2)	1 227 (39.8)	1 436 (45.6)	1 916 (52.8)	*<0.001*
Anastomosis or stoma	Anastomose	6 319 (63.8)	2 058 (67.6)	2 033 (65.4)	2 228 (65.5)	
	Anastomose & stoma	1 236 (12.5)	333 (10.9)	412 (13.2)	491 (14.4)	*0.001*
	Stoma	2 002 (20.1)	655 (21.5)	665 (21.4)	682 (20.1)	

Abbreviations: CI, 95% confidence interval; BMI, Body Mass Index; ASA, American Society of Anaesthesiologists risk score; Left colon, left colon and colon transversum; TNM, Classification of Malignant Tumors; RT, radiotherapy; Gy, gray. Statistical analyses performed using Chi-square test or one-way Anova. *Other characteristics are mainly based on surgeon-choice; therefore they were not used for composing the multivariate model for risk-adjustment.

between hospitals, crude RDs were followed by (in parentheses) risk-adjusted RDs/ odds ratios (OR) for differences in patient characteristics and hospitals as random effects. Adjusted outcomes were estimated by using univariate and multivariate mixed effects models with hospitals as random effects to account for the presence of variability between hospitals. Mixed effects models are designed to handle nested data (like patients in each hospital) and unequal group study. The likelihood ratio test, used to assess whether the variance of the random effect is significant, was highly statistically significant in all estimated models, suggesting that the mixed models are required for the outcomes under study [17,18]. Because outcomes such as hospital length of stay and costs are right-skewed, a log-transformation has been applied to the outcomes of interest before fitting the model of interest.

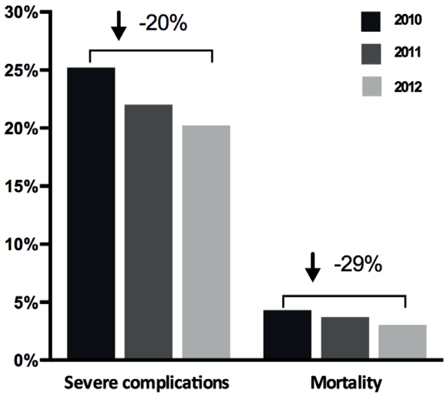


Figure 1. Clinical outcomes after colorectal surgery

	2010	2011	2012	Comparison 2010 vs 2012			
Number of patients	3131	3152	3630	**RD**	OR/ RD (95% CI)*		*p*-value*
Severe complication (%)	25.2%	22.0%	20.2%	**-20%**	0.739	(0.653 : 0.836)	<0.001
Mortality (%)	4.2%	3.7%	3.0%	**-29%**	0.757	(0.571 : 1.003)	0.05
LOS (days)	13.5	12.4	11.7	**-13%**	-11%	(-14% : -8%)	<0.001

Improved clinical outcomes between 2010 and 2012 (clinical data retrieved from the Dutch Surgical Colorectal Audit): Severe complication rate, mortality and length of hospital stay stratified by year of surgery. Arrow represents relative difference between 2010 and 2012.
Abbreviations: RD, relative difference; CI, confidence interval; LOS, mean length of stay of primary admission.
* Risk-adjusted OR's and RD's for differences in patient characteristics and hospitals as random effect.

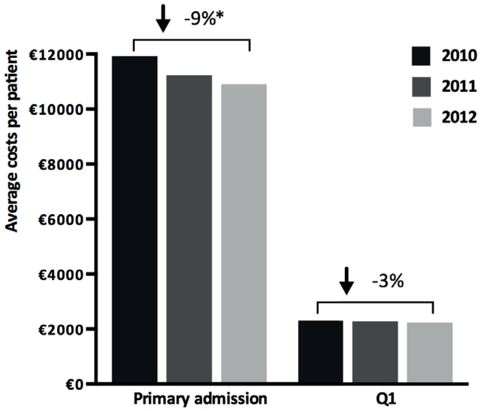


Figure 2. Financial outcomes after colorectal cancer surgery
Average costs of a colorectal cancer patient by year of surgery. Costs for primary admission significant decreases without an increase in costs during Q1. Arrow represents relative difference 2010 vs 2012. Abbreviations: Q1, first 90 days after discharge. * Significant different after risk-adjustment for differences in patient characteristics and hospitals as random effect (RD -7%, CI -10%: -5%, p<0.001).

The second analysis focused on hospital performance in terms of costs and severe complication rate. An unadjusted descriptive analysis (Figure 3A) and a risk-adjusted analysis (Figure 3B) were performed. To compute the risk-adjusted average costs or severe complications rate per each center, a multiple linear mixed regression model (log-transformation has been applied) or a mixed regression model was used (with hospital as random effects to account for the presence of variability between hospitals).

For the third (descriptive) analysis (Figure 4), hospitals were stratified by whether they improved or worsened for severe complications between 2010 and 2012: worsened hospitals (crude RD < 0%), improved hospitals (crude RD 0% to 10%), and strongly improved hospitals (crude RD > 10%). Unadjusted hospital averages for severe complications and costs per patient (costs of primary admission up to 90 days after discharge) were used because patient characteristics at hospital level hardly differed between 2010 and 2012 (data not shown). Means per group were calculated using hospital averages. Statistical analyses were performed by using SPSS (version 22; IBM) and R (version 18). Confidence intervals (CI) were stated at 95%.

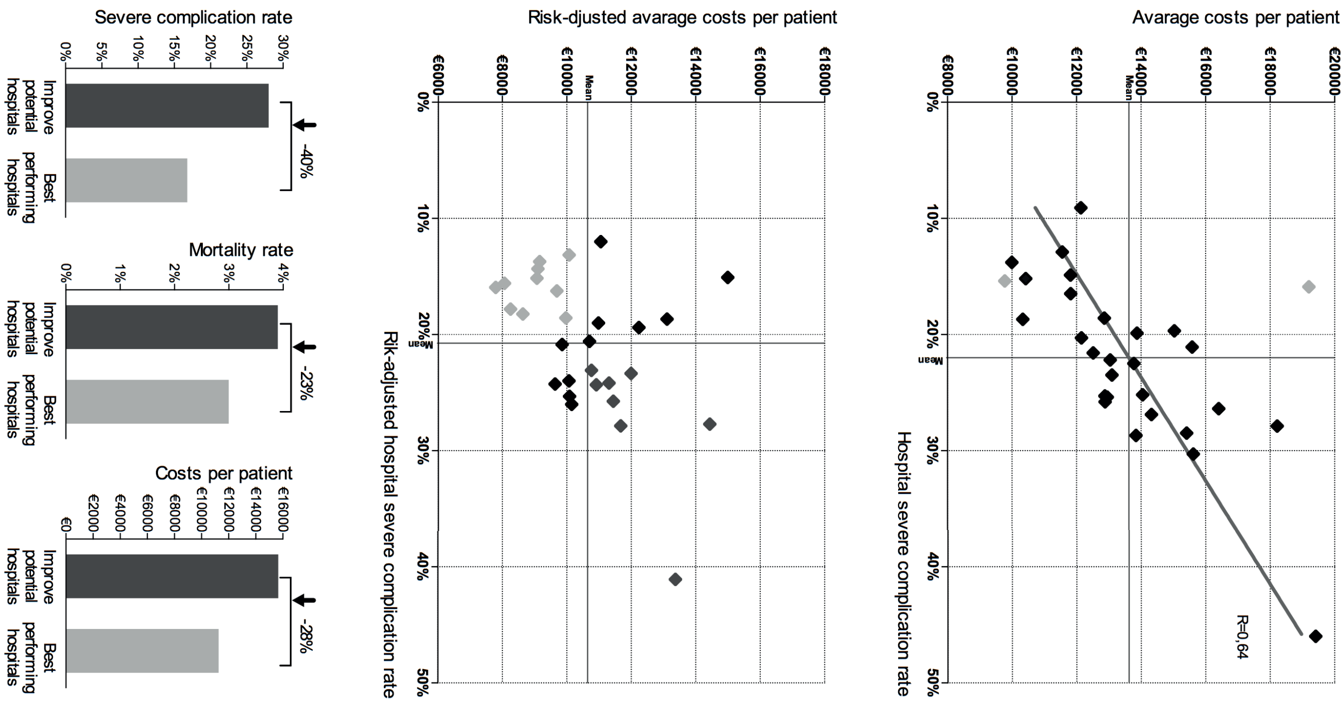


Figure 3. Variation in hospital quality and average costs; identifying 'best practices'

3a. Quality and costs: hospitals' unadjusted severe complication rate is plotted against hospitals' average unadjusted costs of a colorectal cancer patient (primary admission and Q1). Each diamond represents an individual hospital. An inverse relationship (correlation coefficient = 0.64) was identified between severe complication rate and costs. Also considerable variation in average costs per patient is seen between hospitals with similar complication rates (indicated by grey diamonds).

Abbreviations: Q1, first 90 days after discharge.

3b. Identifying best practice hospitals: hospitals' risk-adjusted severe complication rate is plotted against hospitals' average risk-adjusted costs of a colorectal cancer patient (primary admission and Q1). Each diamond represents an individual hospital. Hospitals in left under quadrant are referred as 'best performing' hospitals (light grey, n=10, 3524 patients); hospitals in the upper right quadrant are referred as 'improve potential' hospitals (dark grey, n=8, 3320 patients).

3c. Differences in outcomes between 'best performing' and 'improve potential' hospitals (figure 3b): average severe complication rate, average mortality rate and average costs per colorectal cancer patient for both groups are shown. Outcomes are unadjusted. Costs are for primary admission and Q1. Arrow represents relative difference between two groups.

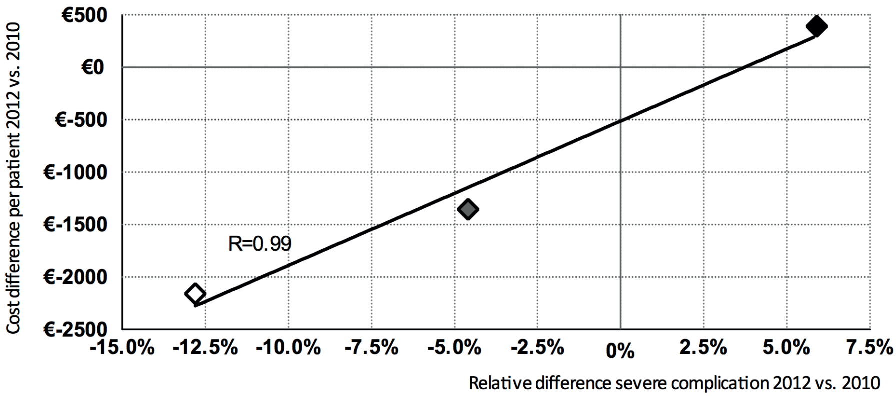


Figure 4. Hospitals with strong quality improvement have higher reduction in costs
Hospitals stratified by relative difference for severe complication between 2010 and 2012. In black hospitals that worsened (=<0% improvement in severe complication rate), in grey hospitals that improved (=0%-10% improvement in severe complication rate) and white hospitals that strongly improved (>10% improvement in severe complication rate). Unadjusted outcomes are shown.

	N (hospitals)	Mean RD*	Cost reduction**
Worsened hospitals (<0% improvement)	7	5.9%	€390
Improved hospitals (0-10% improvement)	12	-4.6%	-€1,353
Strong improved hospitals (>10% improvement)	10	-12.8%	-€2,158

*Mean relative difference in severe complications.
** Mean cost reduction per patient (by using hospital averages).

RESULTS

A total of 9,913 patients were eligible for analysis. All analyzed patient, tumor, and operation characteristics of the studied population are shown in Table 1.

Differences between three consecutive years

Between 2010 and 2012, severe complication rate, mortality rate, and length of hospital stay respectively declined by 20% (risk-adjusted OR 0.739, 95% CI 0.653 to 0.836, p < 0.001), 29% (risk-adjusted OR 0.757, 95% CI 0.571 to 1.003, p = 0.05), and 13% (risk-adjusted RD -12%, 95% CI -15% to -9%, p < 0.001) (Figure 1). The median length of hospital stay declined from 9 days (2010) to 8 days (2012). Financial outcomes were grouped by resource category, as shown in Supplemental Table 1.

Between 2010 and 2012, total costs declined by 8% (risk-adjusted RD -7%, 95% CI -9 to -4%, p < 0.001). In detail, a reduction was seen for costs related to operation, ward, intensive care, radiology, laboratory, and material. Only in the category "other costs" was an increase seen between 2010 and 2012 (Table 2). Between 2010 and 2012, costs during primary admission significantly decreased by 9% (risk-adjusted RD -7%, 95% CI -10% to -5%, p < 0.001). Costs during Q1 decreased by 3%, although this was not statistically significant (risk-adjusted RD -2%, 95% CI -10% to 6%, p = 0.65) (Figure 2). Odds ratios and RDs between 2010 and 2012 without risk adjustment for differences in patient characteristics are shown in Supplemental Table 3.

Table 2. Average costs of one colorectal cancer patient stratified by year of operation

	2010	2011	2012	RD
Operation	€ 3 799	€ 3 856	€ 3 774	-1%
Ward	€ 5 391	€ 5 003	€ 4 716	-13%
Intensive care	€ 2 866	€ 2 483	€ 2 514	-12%
Radiology	€ 265	€ 251	€ 240	-9%
Laboratory	€ 786	€ 775	€ 751	-4%
Consulting	€ 410	€ 423	€ 404	-1%
Materials	€ 260	€ 208	€ 211	-19%
Other	€ 461	€ 513	€ 535	+16%
Total	**€ 14 237**	**€ 13 512**	**€ 13 145**	**-8%***

Average costs per patient (total costs of primary admission up to 90 days after discharge) by resource category stratified by year of surgery. Abbreviations: RD, relative difference. *Risk-adjusted RD -7%, CI -9%: -4%, p<0.001 (risk-adjustment for differences in patient characteristics and for hospitals as random effect).

Differences between hospitals

The average severe complication rate per hospital varied from 9.1% to 46% (Figure 3A). The average costs (primary admission and Q1) per hospital of a colorectal cancer patient ranged from €9,777 to €19,417 (Figure 3A). At the hospital level, a correlation was identified between severe complication rate and average costs per patient (correlation coefficient [R] = 0.64, Figure 3A). Variation in average costs per patient between hospitals with comparable severe complication rates was identified, for example, for the 2 hospitals indicated with grey diamonds in

Figure 3A (the lighter grey hospital had 49% lower costs compared with the other hospital). A weak correlation was identified between mortality rate and hospital costs (R = 0.25). Analyses were repeated with adjustment for differences in patient characteristics in order to compare hospital performances (Figure 3B). Hospitals with lower adjusted severe complication rates than the adjusted average (< 20.1%) and with lower adjusted costs than the adjusted average (< €10,645) were defined as “best performing” hospitals (lower left quadrant in Figure 3B [n = 10; 3,524 patients], average is calculated at hospital level). Hospitals with higher adjusted severe complication rates than the adjusted average (> 20.1%) and with higher adjusted costs than the adjusted average (> €10,645) were defined as “improve potential” hospitals (upper right quadrant in Figure 3B, n = 8; 3,320 patients). “Best performing” hospitals were associated with a lower crude severe complication rate (-40%), lower crude mortality rate (-23%), and lower crude average costs per patient (-28%), as compared with “improve potential” hospitals (Figure 3C). Hospitals that were not able to improve their severe complication rate between 2010 and 2012 (crude RD < 0%, n = 7) were not able to reduce costs (€-390). Hospitals that improved between 2010 and 2012 (crude RD 0% to 10%, n = 12) or strongly improved (crude RD > 10%, n = 10) made remarkable savings (€1,353 and €2,158 per patient, respectively) (Figure 4).

DISCUSSION

This article presents evidence for the inverse relationship between quality improvement and health care costs. By participating in a nationwide quality improvement initiative, and therefore enabling continuous quality measurement and benchmarked feedback, clinical outcomes of patients undergoing colorectal cancer surgery improved in 3 consecutive years (Figure 1), with a simultaneous substantial reduction in hospital costs (Figures 2 and 4). In addition, this report highlights variation between hospitals in quality of care as well as costs per patient. This enables identification of “best practice” hospitals, providing high quality care for relatively low costs (Figure 3). Revealing the high leverage processes of care behind

these "best practices" gives the opportunity to bring the medical field forward in improving the value of health care delivery [3,13].
As shown in a recent review of the literature, studies describing the inverse relationship between quality improvement and hospital costs by quality improvement programs are scarce [19]. This is the first study outside the United States to describe such an inverse relationship based on original financial and clinical data. Therefore, our conclusions provide additional evidence for cost reduction by quality improvement programs, as seen in the American College of Surgeons National Surgical Quality Improvement Program [20-22]. Existing studies were, however, hampered by their reliance on single-center data [20] or by a lack of uniformity and/or transparency in cost registration between different institutions, and therefore using proxies of real costs, like fixed costs of complications [21,22] or claim payments [23]. In addition to those earlier studies, this multicenter study analyzed detailed clinical data (Table 1) combined with actual costs for every individual patient, based on time-driven activity-based costing [9] which is an advanced method for understanding hospitals costs [13,14]. Moreover, extensive registration of clinical information in the DSCA resulted in availability of detailed patient characteristics (Table 1). This enabled appropriate risk-adjustment in the comparison of hospital performances (Figure 3B), as high-risk patients are not evenly distributed between hospitals [15].
A recent study of Eappen and colleagues [24] noted that some hospitals (depending on payer mix) have the potential for adverse near-time financial consequences when decreasing post-surgical complications. Under some payers, the occurrence of surgical complications was associated with higher hospital contribution margins (revenue minus variable costs), therefore providing a perverse stimulus for health care providers. The Dutch health care system does not have different reimbursements for patients with or without complications, so reducing (severe) complications in Dutch hospitals (Figure 1) will directly benefit hospital finances (Table 2).
Conclusions based on this study support the value based health care theory of Michael Porter [3,13,25]. Porter advises health care providers to focus on optimizing value for patients, describing value as "the health outcomes achieved that matter to patients, relative to the costs of achieving those outcomes." As seen in this study, the reduction of complications after colorectal surgery is undoubtedly beneficial to

patients and reduces costs for providers as well [26]. A recent article from our group described several key elements crucial for the success of the DSCA [7], including the leading role of the Association of Surgeons of the Netherlands, performance indicators based on evidence-based guidelines, web-based registration by (or under the supervision of) medical specialists themselves, weekly updated feedback of indicator results to participants, and annual external data verification with other data sources. By providing continuous feedback of benchmarked performance information to colorectal surgeons, existing problems in their care process are identified and improved. Guideline adherence has improved significantly since the beginning of the DSCA, as evidenced by the number of complete preoperative colonoscopies, the percentage of cases preoperatively discussed in a multidisciplinary team, and the percentage of circumferential resection margins reported in the pathology report after rectal cancer resection. [7].

Because the extensive registration of patient characteristics in a clinical audit is a cost- and time-consuming exercise [27], one might argue that registration costs should be taken into account in our analyses. Therefore, we also looked at the costs of retrieving, entering, and verifying the data; if costs for participation in the DSCA were incorporated in the analysis, participation would still be cost effective: average costs for clinical auditing in the 29 hospitals was roughly €77 per patient for participation in the audit and additional costs of €43 for entering the data (Supplemental Table 4, online only). This resulted in almost €1.2 million auditing costs for all 3 years. Total cost reduction for 2011 and 2012 was more than €6.2 million (yearly cost reduction per patient multiplied by yearly volume in 2011 and 2012, retrieved from Table 2) resulting in a 3-year overall net saving of more than €5 million.

We also developed a method to identify “best practice” hospitals, by combining clinical outcomes with financial outcomes. As shown in Figure 3A, hospitals shown in light grey belong to the quartile of hospitals with lowest severe complication rates. Although both these hospitals had low severe complication rates, 1 hospital spent 49% less money than the other hospital because of higher costs of the resources used (data not shown). This means that the expensive hospital has a lot of potential to reduce its total costs when it is able to reduce its resource cost.

Therefore, besides looking at quality only, identifying "best practice" hospitals on both dimensions (Figure 3B) might lead to better insights into how to improve quality, reduce needed resources, and save costs. Moreover, finding the group of best practices hospitals will provide a realistic goal for all other hospitals, enabling further development of a sustainable health care system. If, between 2010 and 2012, all hospitals performed on the level of best practice hospitals, the additional savings in this study would have been more than €20 million (Figure 3B, the subgroup of best practice hospitals have €2,340 lower costs per patient [€11,266] than the study average [€13,606]).

According to our hypothesis, the darker grey hospital in Figure 3A could be considered an outlier (low complication rate but expensive). Therefore, we repeated the analyses at hospital level after excluding this outlier, and this resulted in a higher correlation coefficient (R = 0.80) compared with that in the previous analysis, providing even stronger evidence for our study hypothesis.

Limitations

First, there might be other reasons for the established quality improvement during this time period, such as the Enhanced Recovery After Surgery (ERAS) protocol or secular trends not registered in the DSCA. However, the ERAS protocol was already implemented in the Netherlands before 2010. Moreover, without availability of key data on outcomes, health care organizations are flying blind in deciding what should be targets for quality improvement initiatives. Also a reduction in costs might be established by other reasons than quality improvement programs alone (like pressures on length of stay due to hospital capacity). Second, the increased use of laparoscopic techniques in colorectal surgery (Table 1) might have had a positive effect on its own in improving clinical outcomes[28] and therefore leading to a reduction in costs[29]. On the other hand laparoscopic surgery can generate costs as well. Since laparoscopic approach for (elective) surgery is a choice a surgeon can make we chose not to include this in the risk-adjustment model (see footnote Table 1). Third, some costs, like specialist fees and costs of medication and dialyses, were excluded in our analyses since registration of these resources were not uniform in the participating hospitals. This might lead to an underestimation of the real costs although we do not expect that this would affect our main findings since it affects all three years. Moreover, one could argue that hospitals with low complication rates have better surgeons, though these surgeons might be more expensive. Although specialist fees where not registered uniformly in the participating hospitals, specialist fees in the Netherlands are quite comparable between public hospitals, making this argument less likely. Fourth, long-term survival of patients is not registered in the DSCA yet. However a number of intermediate parameters, which could be associated to long-term outcome of cancer resections, are available. For example between 2009 and 2011, the percentage of positive Circumferential Resection Margins, a quality indicator for rectal cancer surgery associated with the risk for local recurrence, declined significantly.[7] This was also observed during our study period (data not shown). Although improved outcome on this quality indicator is associated with better long-term survival[30], future follow up studies should be performed to confirm survival benefits in our population. Finally, one might argue that outcomes improved due to regionalization of difficult cases to tertiary centers not participating in this study. However, patient characteristics between the three consecutive years did not change tremendously and the annual volume of procedures increased (Table 1), making referral of patient to other institutions less likely.

Further perspectives

Nationwide outcome registries might serve as an ideal framework to address effectiveness of healthcare since measuring, reporting and comparing outcomes could also guide cost reductions. Analyzing costs should be a standard procedure in the continuous evaluation of care processes in hospitals. In addition, combining clinical and financial outcomes with Patient Reported Outcome Measures (PROMs) provides an even superior ‘best practice’. Risk-adjusted benchmarking on quality, costs and PROMs will enable healthcare providers to learn from best practices and lead to higher quality of care with the use of fewer resources.

CONCLUSIONS

This article supports the Value Based Healthcare agenda [3,13,25] by presenting evidence for the inverse relationship between quality improvement and health care costs. By participation in a nationwide quality improvement initiative with continuous quality measurement and benchmarked feedback, opportunities for targeted improvements are revealed which can bring the medical field forward in continuous improvement of value of healthcare delivery. As research presented in this manuscript suggests, focus in healthcare should shift to initiatives that aim to improve quality and safety of patient care, which will catalyze costs savings.

REFERENCES

1. Arne Björnberg (Health Consumer Powerhouse Ltd. Euro Health Consumer Index 2013. 2013(ISBN 978-91-980687-2-6).
2. The Dutch Ministry of Health WaS. Rijksoverheid, *Rapport 'De zorg: hoeveel extra is het ons waard?'*. 2012.
3. Porter ME. What is value in health care? *The New England journal of medicine.* 2010;363(26):2477-2481.
4. Lothian and Borders large bowel cancer project: immediate outcome after surgery. The consultant surgeons and pathologists of the Lothian and Borders Health Boards. *The British journal of surgery.* 1995;82(7):888-890.
5. Khuri SF, Daley J, Henderson W, et al. The Department of Veterans Affairs' NSQIP: the first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care. National VA Surgical Quality Improvement Program. *Annals of surgery.* 1998;228(4):491-507.
6. Larsson S, Lawyer P, Garellick G, Lindahl B, Lundstrom M. Use of 13 disease registries in 5 countries demonstrates the potential to use outcome data to improve health care's value. *Health Aff (Millwood).* 2012;31(1):220-227.
7. Van Leersum NJ, Snijders HS, Henneman D, et al. The Dutch surgical colorectal audit. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2013;39(10):1063-1070.
8. Dutch Surgical Colorectal Audit.
9. Kaplan RS, Anderson SR. Time-driven activity-based costing. *Harvard business review.* 2004;82(11):131-138, 150.
10. Kolfschoten NE, van Leersum NJ, Gooiker GA, et al. Successful and safe introduction of laparoscopic colorectal cancer surgery in Dutch hospitals. *Annals of surgery.* 2013;257(5):916-921.
11. Performation. http://www.performation.com.
12. Klarenbeek BR, Coupe VM, van der Peet DL, Cuesta MA. The cost effectiveness of elective laparoscopic sigmoid resection for symptomatic diverticular disease: financial outcome of the randomized control Sigma trial. *Surgical endoscopy.* 2011;25(3):776-783.
13. Porter ME, Lee TH. The Strategy That Will Fix Health Care. *Harvard business review.* 2013;91(12):24-24.
14. Mercier G, Naro G. Costing hospital surgery services: the method matters. *PloS one.* 2014;9(5):e97290.
15. Kolfschoten NE, Marang van de Mheen PJ, Gooiker GA, et al. Variation in case-mix between hospitals treating colorectal cancer patients in the Netherlands. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2011;37(11):956-963.
16. Kube R, Ptok H, Jacob D, et al. Modified neoadjuvant short-course radiation therapy in uT3 rectal carcinoma: low local recurrence rate with unchanged overall survival and frequent morbidity. *International journal of colorectal disease.* 2010;25(1):109-117.
17. McCulloch CE, Searle, Shayle R. *Generalized, Linear, and Mixed Models.* 1st ed. New York: John Wiley & Sons; 2001.
18. Lindsey JK, Jones B. Choosing among generalized linear models applied to medical data. *Statistics in medicine.* 1998;17(1):59-68.

19. Govaert JA, van Bommel AC, van Dijk WA, van Leersum NJ, Tollenaar RA, Wouters MW. Reducing Healthcare Costs Facilitated by Surgical Auditing: A Systematic Review. *World journal of surgery.* 2015.
20. Hollenbeak CS, Boltz MM, Wang L, et al. Cost-effectiveness of the National Surgical Quality Improvement Program. *Annals of surgery.* 2011;254(4):619-624.
21. Henke PK, Kubus J, Englesbe MJ, Harbaugh C, Campbell DA. A statewide consortium of surgical care: a longitudinal investigation of vascular operative procedures at 16 hospitals. *Surgery.* 2010;148(4):883-889; discussion 889-892.
22. Guillamondegui OD, Gunter OL, Hines L, et al. Using the National Surgical Quality Improvement Program and the Tennessee Surgical Quality Collaborative to improve surgical outcomes. *Journal of the American College of Surgeons.* 2012;214(4):709-714; discussion 714-706.
23. Birkmeyer JD, Gust C, Dimick JB, Birkmeyer NJ, Skinner JS. Hospital quality and the cost of inpatient surgery in the United States. *Annals of surgery.* 2012;255(1):1-5.
24. Eappen S, Lane BH, Rosenberg B, et al. Relationship between occurrence of surgical complications and hospital finances. *Jama.* 2013;309(15):1599-1606.
25. Porter ME. A strategy for health care reform--toward a value-based system. *The New England journal of medicine.* 2009;361(2):109-112.
26. Govaert JA, Fiocco M, van Dijk WA, et al. Costs of complications after colorectal cancer surgery in the Netherlands: Building the business case for hospitals. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2015.
27. Hammermeister K. The National Surgical Quality Improvement Program: learning from the past and moving to the future. *American journal of surgery.* 2009;198(5 Suppl):S69-73.
28. Schwenk W, Haase O, Neudecker J, Muller JM. Short term benefits for laparoscopic colorectal resection. *Cochrane Database Syst Rev.* 2005(3):CD003145.
29. Braga M, Frasson M, Zuliani W, Vignali A, Pecorelli N, Di Carlo V. Randomized clinical trial of laparoscopic versus open left colonic resection. *The British journal of surgery.* 2010;97(8):1180-1186.
30. Wibe A, Rendedal PR, Svensson E, et al. Prognostic significance of the circumferential resection margin following total mesorectal excision for rectal cancer. *The British journal of surgery.* 2002;89(3):327-334.

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

Supplemental Table 2. Outcomes after colorectal cancer surgery for the participating hospitals in this study (29 hospitals) as compared to national outcomes (all 92 hospitals)

	This study			National outcomes*		
	2010	2011	2012	2010	2011	2012
Number patients	3131	3152	3630	7888	8757	9556
Mortality	4%	4%	3%	4%	3%	3%
Major morbidity	25%	22%	20%	24%	21%	20%

* Data retrieved form the Dutch Surgical Colorectal Audit annual reports 2010 – 2012 (www.clinicalaudit.nl).

Supplemental table 3. Relative difference 2010 - 2012 without risk-adjustment for differences in patient characteristics

		Univariate analyses		
	Crude RD	OR/ RD	95% CI	P-value
Severe complications	-20%	0.758	(0.675: 0.850)	<0.001
Mortality	-29%	0.698	(0.539: 0.903)	0.006
Costs primary admission	-9%	-7%	(-10%: -4%)	<0.001
Costs Q1	-3%	+1%	(-7%: 10%)	0.76
Total costs	-8%	-6%	(-9%: -3%)	<0.001

All outcomes were only adjusted for hospitals as random effect. Abbreviations: RD, relative difference; OR, odds ratio; CI, confidence interval.

Supplemental Table 4. Yearly costs of clinical auditing in 2012

		Price	N	Total price
Fixed costs	Yearly hospital fee	€ 3 000	29	€ 87 000
	Monthly hospital fee	€ 300	29 x 12	€ 104 400
Variable costs	Fee per patient	€ 25	3627	€ 90 675
	Costs of registration*	€ 17	3627	€ 61 659
	Costs of verification**	€ 26	3627	€ 92 489
Total costs	All patients in 29 hospitals	€ 120	3627	€ 436 223

Costs based on Dutch Surgical Colorectal Audit 2013 fee. *Based on 30 minutes of registration by a Physician Assistant (year salary €60,000). **Based on 15 minutes of verification by a surgeon (yearly salary €180,000).

CHAPTER 4

J.A. Govaert
M. Fiocco
W.A. van Dijk
A.C. Scheffer
E.J.R. de Graaf
R.A.E.M. Tollenaar
M.W.J.M. Wouters

COSTS OF COMPLICATIONS AFTER COLORECTAL CANCER SURGERY IN THE NETHERLANDS: BUILDING THE BUSINESS CASE FOR HOSPITALS

European Journal of Surgical Oncology 2015

On behalf of the Dutch Value Based Healthcare Study Group

B. Lamme, MD, PhD (Albert Schweitzer Ziekenhuis, Dordrecht); D.A. Hess MD, PhD (Antonius ziekenhuis, Sneek); H.J. Belgers, MD (Atrium-Orbis, Heerlen); O.R. Guicherit, MD, PhD (MCH-Bronovo, Den Haag); C. Rosman, MD, PhD (Canisius Wilhelmina Ziekenhuis, Nijmegen); Prof H.J.T. Rutten, MD, PhD (Catharina Hospital, Eindhoven/ Maastricht University Medical Hospital, Maastricht); F.N.L. Versluijs-Ossewaarde. MD (Diaconessenhuis, Meppel); E.S. Van der Zaag, MD, PhD (Gelre Ziekenhuizen, Apeldoorn); L.N.L. Tseng, MD (Groene Hart Ziekenhuis, Gouda); E.J.R. de Graaf, MD, PhD (IJsselland Hospital, Capelle aan den Ijssel); W.J. Vles, MD, PhD (Ikazia Ziekenhuis, Rotterdam); E.G.J.M. Pierik, MD, PhD (Isala Kliniek, Zwolle); H.A. Prins, MD, PhD (Jeroen Bosch Ziekenhuis, Den Bosch); P.H.M. Reemst, MD (Máxima Medisch Centrum, Veldhoven); E.C.J. Consten, MD, PhD (Meander Medisch Centrum, Amersfoort); S.A. Koopal, MD PhD (Medisch Centrum Leeuwarden, Leeuwarden); P.A. Neijenhuis, MD, ScS (Alrijne Ziekenhuis, Leiderdorp); G.H.H. Mannaerts, MD, PhD (Sint Franciscus Gasthuis, Rotterdam); A.B. Smits, MD (St. Antonius Ziekenhuis, Nieuwegein); D.H.C. Burger, MD (Elisabeth-Tweesteden Ziekenhuis, Tilburg); M.G.A. van IJken, MD, PhD (Van Weel-Bethesda Ziekenhuis, Dirksland); P. Poortman, MD, PhD (Waterlandziekenhuis, Purmerend); M.J.P.M. Govaert, MD (Westfriesgasthuis, Hoorn); W.A. Bleeker, MD, PhD (Wilhelmina Hospital Assen); F.C. Den Boer, MD, PhD (Zaans Medical Center); F. Wit, MD (Ziekenhuis Tjongerschans, Heerenveen); Ph. M. Kruyt, MD (Ziekenhuis Gelderse Vallei, Ede); A. Mearadji, MD, PhD (Bravis Ziekenhuis, Bergen op Zoom); J.T. Heikens, MD, PhD (Ziekenhuis Rivierenland, Tiel)

ABSTRACT

Background

Healthcare providers worldwide are struggling with rising costs while hospitals budgets are under stress. Colorectal cancer surgery is commonly performed, however it is associated with a disproportionate share of adverse events in general surgery. Since adverse events are associated with extra hospital costs it seems important to explicitly discuss the costs of complications and the risk factors for high-costs after colorectal surgery.

Methods

Retrospective analysis of clinical and financial outcomes after colorectal cancer surgery in 29 Dutch hospitals (6768 patients). Detailed clinical data was derived from the 2011-2012 population-based Dutch Surgical Colorectal Audit database. Costs were measured uniform in all participating hospitals and based on Time-Driven Activity-Based Costing.

Findings

Of total hospital costs in this study, 31% was spent on complications and the top 5% most expensive patients were accountable for 23% of hospitals budgets. Minor and severe complications were respectively associated with a 26% and 196% increase in costs as compared to patients without complications. Independent from other risk factors, ASA IV, double tumor, ASA III, short course preoperative radiotherapy and TNM-4 stadium disease were the top-5 attributors to high costs.

Conclusions

This article shows that complications after colorectal cancer surgery are associated with a substantial increase in costs. Although not all surgical complications can be prevented, reducing complications will result in considerable cost savings. By providing a business case we show that investments made to develop targeted quality improvement programs will pay off eventually. Results based on this study should encourage healthcare providers to endorse quality improvement efforts.

INTRODUCTION

Nowadays, healthcare providers worldwide are struggling with rising costs while hospitals budgets are under stress. In response to the current demand for financial transparency, it seems important to explicitly discuss underlying costs of services provided. Earlier studies showed that hospital costs are associated with quality of healthcare where hospitals providing high quality care have lower costs [12]. Postoperative complications lead to increased resource utilization and as a consequence to higher healthcare costs [3-9]. Therefore more and more pressure is being exerted on health care providers to simultaneously improve quality and reduce costs of health care provided.

Colorectal cancer surgery is a commonly performed procedure, but remains associated with high postoperative morbidity and mortality and accounts for an extraordinary share of adverse events in general surgery [10]. In the Netherlands, roughly 10000 colorectal cancer procedures are performed every year [11]. As of 2009, detailed patient and outcome characteristics of colorectal surgery are registered in the nationwide Dutch Surgical Colorectal Audit (DSCA) to monitor, evaluate and improve colorectal cancer care[11,12]. In order to facilitate improvement initiatives aiming for a decrease in healthcare costs by reducing complications, the primary objective of the current study was to explore the association between complications after colorectal cancer surgery and hospital costs. To analyze the financial impact of complications also after hospitalization, we included hospitals costs up to 90 days after discharge. A secondary aim of the present study was to investigate the existence of common risk factors for complications and their associated costs.

PATIENTS AND METHODS

Clinical data

The data set was retrieved from the Dutch Surgical Colorectal Audit (DSCA) a nationwide, population based database where detailed patient, tumor, diagnostic, procedural and outcome data are registered for patients who undergo a resection of a primary colorectal carcinoma in the Netherlands. The dataset shows a nearly 100% completeness on most items and high accuracy level of validation compared to the Netherlands Cancer Registry [11,12]. A detailed description of the DSCA has been published recently [12,13].

Financial data

The economic evaluation was conducted from a hospital perspective. Therefore only 'in-hospital' costs were considered in this study. Costs were taken into account from the day of initial surgery till discharge (= primary admission) up to 90 days after discharge (= Q1). Resource utilization at patient level was extracted from the Hospital Information System from each participating hospital. For each hospital, translation of patient level resource utilization into costs was provided by Performation (Bilthoven, The Netherlands), which is a healthcare consultancy firm providing patient level costing and benchmarking products for more than 100 hospitals across Europe [14,1516]. Costs were calculated by using Time-Driven Activity-Based Costing (TD-ABC) methodology [17] which is an advanced method for understanding hospitals costs[18]. Cost price calculations are 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 both years (2011 and 2012) to avoid differences due to inflation or to the different models themselves. Different activities are grouped into eight categories as shown in Supplemental Table 1. All activities consisted of direct (e.g. personnel staff, material and equipment) and indirect costs. For example, direct costs for an inpatient day (category 'ward') consisted of (a) personnel as salary of ward nurses and administrative personnel, (b) material costs as bed linen and bandages and (c) depreciation of equipment such as ward inventory. Examples of indirect costs are those related to information technology, building depreciation, cleaning, catering, etc. Specialists' fees, medication and dialyses costs were excluded since registration of these parameters was not uniform in all participating hospitals making equal comparison impossible.

Inclusion criteria

Hospital selection (n = 29) was based on the availability of detailed cost-price information for two consecutive years. In these hospitals approximately a third of the entire colorectal cancer surgery procedures annually performed in the Netherlands was carried on. From the 29 hospitals, 21 (72%) have a surgical teaching program. Patients undergoing surgical resection for primary colorectal cancer between January 1st, 2011 and December 31st, 2012 had to be registered in the DSCA before December 1st 2013. Minimal data requirements to consider a patient eligible for matching with the financial dataset was information concerning tumor location, date of surgery and mortality status.

Match

Unique Patient Identification Number (UPIN) combined with hospital of admission was used to match patients registered in the DSCA to their information in the financial database. For those without a match on UPIN four different patient characteristics were matched (date of birth, gender, hospital of admission and date of surgery). This method resulted in a data set of 6782 eligible patients (match > 99%).

Definitions

Two different methods of analyzing complications were used. The first method divided complications into two groups as described earlier [19,20]: (1) mild complications, defined as any complication occurring within 30 days after resection and not being a severe complication and (2) severe complications, defined as a complication with serious consequences: leading to mortality, a reintervention (operative or percutaneous), or a postoperative hospital stay of at least 14 days. Any patient not having a mild or severe complication was analyzed as 'no complication'. The second method classifies complications in 7 categories: (1) surgical complications, (2) pulmonary complications, defined as a complication mainly related to the lung (except for pulmonary embolism), e.g. bacterial pneumonia or viral pneumonia. (3) Cardiac complications, defined as a complication which cause is related to the heart, e.g. cor pulmonale or myocardial infarction. (4) Neurologic complications, defined as a complication which cause is related to the nerve system or brain, e.g. cerebrovascular accident. (5) Infectious complications defined as any infection other than surgical infection or pneumonia, e.g. urinary tract infection. (6) Thromboembolic complications, defined as a complication which cause is related to the blocking of a blood vessel due to the formation of a blood clot (except for cerebral accidents), e.g. pulmonary embolism or deep vein thrombosis. (7) Other complications, defined as any complication not listed in any of the categories above. Outcome measures for costs of healthcare were (1) hospital costs of primary admission, (2) hospital costs after discharge up to 90 days (= Q1), (3) total hospital costs (= hospital costs of primary admission and Q1) (4) length of hospital stay, (5) length of intensive care (IC) stay and (6) operation time.

Statistical analyses

Chi-square test and one-way Anova were used to investigate differences between patients' characteristics (Table 1).

Three different analyses were performed in this study. In the first analysis cost differences between patients with none-, mild- or severe complications were analyzed. Costs were calculated for primary admission, first 90 days after discharge (Q1) and total costs (primary admission and Q1). Mixed model with hospitals as random effects were used to account for the presence of possible variability between hospitals and are designed to handle nested data (like patients in each hospital) and unequal group study [21,22].

The second method analyzed differences in total costs (primary admission and Q1) among 7 categories of complications by using multivariate regression models with hospitals as random effects. First, the analysis was performed without risk-adjustment; then with risk-adjustment for patient's characteristics illustrated in Table 1; in the last analysis risk-adjustment for patient's characteristics and all type of complications were included in the mixed model. Only patients' characteristics that did not depend on choices made by a surgeon were used for the risk-adjustment model (therefore surgical approach and construction of a stoma were not used for risk-adjustment) (Table 1).

In the third analysis risk factors (patient characteristics listed in Table 1) associated with severe complications and total costs (primary admission and Q1) were investigated by using multivariate regression models with hospitals as random effects. Statistical analyses were performed by using SPSS (version 20; IBM) and R (version 18). Outcomes are presented as the mean. Confidence intervals (CI) were stated at 95%.

RESULTS

A total of 6782 patients were eligible for analysis. 819 patients (12.1%) suffered from mild complications, 1426 patients (21.0%) suffered from severe complications. All analyzed patient, tumor and procedural characteristics of the studied population are shown in Table 1.

Distribution of costs and additional costs of complications

Patients were grouped as 2.5% (n = 170) of the whole analyzed population: average total costs (primary admission and Q1) for patients ranged from €3403 (least expensive 2.5%) to €79953 (most expensive 2.5%). The top 5% most expensive patients were accountable for 23% of the total hospital costs analyzed in this study (Figure 1A). Highest total costs for one single patient was €205946.

Total hospital costs (primary admission and Q1) of our studied population was €90.308 million (100%). Average costs for one patient without complications was €9226. This resulted in €62.569 million (69%) in 'baseline' costs (€9226 X 6782 patients). Patients with mild and severe complications were respectively associated with €1.984 million (2%) and €25.755 million (29%) additional costs (Figure 1B).

Table 1. Patient, tumor and treatment characteristic of patients enrolled in this study with no, mild or severe complications

		Total		**No complication**		**Mild complication**		**Severe complication**		
		N	%	N	%	N	%	N	%	*p*-value
Total		6782		4537	66.9%	819	12.1%	1426	21.0%	
Characteristics for risk-adjustment										
Sex	Male	3734	55.1%	2357	52.0%	491	60.0%	886	62.1%	<0.001
BMI (mean)		26.2		26.07		26.41		26.33		0.038
Age (mean)		69.8		69.14		70.47		71.40		<0.001
Charlson score	Charlson 0	3621	53.4%	2534	55.9%	438	53.5%	649	45.5%	<0.001
	Charlson 1	1544	22.8%	1013	22.3%	194	23.7%	337	23.6%	
	Charlson 2+	1617	23.8%	990	21.8%	187	22.8%	440	30.9%	
ASA score	I-II	5092	75.1%	3587	79.3%	601	74,0%	904	63.7%	<0.001
	III	1558	23.0%	893	19.7%	204	25.1%	461	32.5%	
	IV-V	105	1.5%	44	1.0%	7	0.9%	54	3.8%	
Double tumor	Yes	247	3.6%	148	3.3%	27	3.3%	72	5.0%	0.006
Tumor location	Right colon	2150	31.7%	1464	32.3%	258	31.5%	428	30.0%	<0.001
	Left colon	795	11.7%	529	11.7%	89	10.9%	177	12.4%	
	Sigmoid	1810	26.7%	1285	28.3%	192	23.4%	333	23.4%	
	Rectum	2027	29.9%	1259	27.7%	280	34.2%	488	34.2%	
Tumor stage (TNM)	Stadium unknown	125	1.8%	97	2.2%	9	1.1%	19	1.3%	0.005
	Stadium 0	156	2.3%	108	2.4%	18	2.2%	30	2.1%	
	Stadium 1	436	6.4%	319	7.1%	47	5.8%	70	5.0%	
	Stadium 2	1408	20.8%	930	20.6%	170	20.9%	308	21.9%	
	Stadium 3	3723	54.9%	2494	55.3%	468	57.4%	761	54,0%	
	Stadium 4	887	13.1%	563	12.5%	103	12.6%	221	15.7%	

Table 1. Patient, tumor and treatment characteristic of patients enrolled in this study with no, mild or severe complications (continued)

		Total		**No complication**		**Mild complication**		**Severe complication**		
		N	%	N	%	N	%	N	%	*p*-value
Preoperative radiotherapy	None	5051	74.5%	3483	76.8%	571	69.7%	997	69.9%	<0.001
	5 x 5 Gy	941	13.9%	547	12.1%	134	16.4%	260	18.2%	
	60 Gy / else	790	11.6%	507	11.2%	114	13.9%	169	11.9%	
Distant metastases	Yes	705	10.4%	459	10.1%	83	10.1%	163	11.4%	0.354
Metastasectomy	Yes	227	3.3%	142	3.1%	29	3.5%	56	3.9%	0.326
Extended resections	Yes	572	8.4%	360	7.9%	83	10.1%	129	9.0%	0.073
Urgency of resection	Urgent	902	13.3%	525	11.6%	114	13.9%	263	18.5%	<0.001
Other characteristics										
Surgical approach	Laparoscopic	3352	49.4%	2456	54.2%	329	40.2%	567	39.8%	<0.001
Anastomosis or stoma	Anastomose	4261	62.8%	3035	69.8%	458	58.7%	768	55.7%	<0.001
	Anastomose & stoma	903	13.3%	514	11.8%	120	15.4%	269	19.5%	
	Stoma	1347	19.9%	802	18.4%	202	25.9%	343	24.9%	

Abbreviations: CI, 95% confidence interval; BMI, Body Mass Index; ASA, American Society of Anesthesiologists risk score; Left colon, including transverse colon; TNM, Classification of Malignant Tumors; Gy, gray. Statistical analyses performed using Chi-square test or one-way Anova.

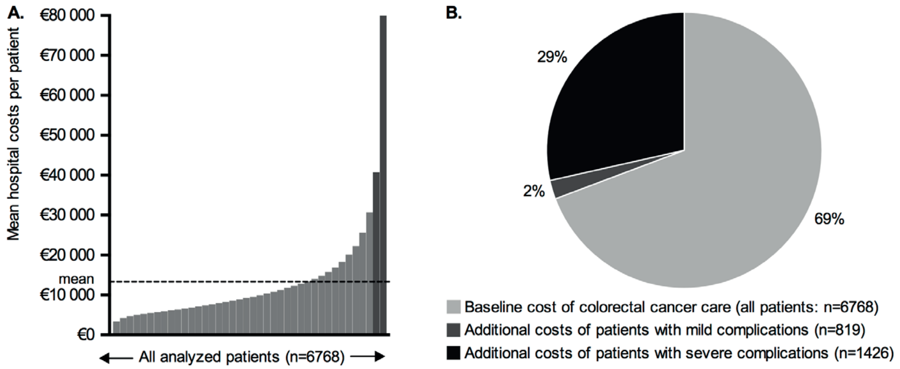


Figure 1. Illustrative picture: Distribution of costs and additional costs of patients with complications
A. Each bar represents mean costs of 2,5% (170 patients) of the analyzed patients in this study. Top 5% most expensive patients (two dark grey bars) are accountable for 23% of the total costs.
B. Baseline costs are accountable for 69% (€62 million) of total hospital costs. Patients with mild and severe complications are respectively accountable for 2% (€2 million) and 29% (€26 million) additional costs.

Minor and severe complications

Costs related to primary admission only were higher for patients with minor (€9061) and severe complications (€23616) as compared to patients without complications (€7470). Using the mixed model with hospitals as random effects costs significant increased for patients with minor and severe complications with respectively €1623 (CI €795: €2451, p < 0.001) and €16059 (CI €15401: €16716, p < 0.001).
Costs related to the first 90 days after discharge were higher for patients with minor (€2587) and severe complications (€3671) as compared to patients without complications (€1756). Using the mixed model with hospitals as random effects costs significantly increased for patients with minor and severe complications with respectively €799 (CI €415: €1183, p < 0.001) and €1869 (CI €1564: €2174, p < 0.001) (Figure 2).

For total hospital costs (primary admission and Q1) minor complications were associated with a significant 26% increase in costs. Using the mixed model with hospitals as random effects costs significantly increased with €2403 (CI €1497: €3309, p < 0.001). This increase mainly depended on higher costs in the categories ward, intensive care and operation (Table 2A).

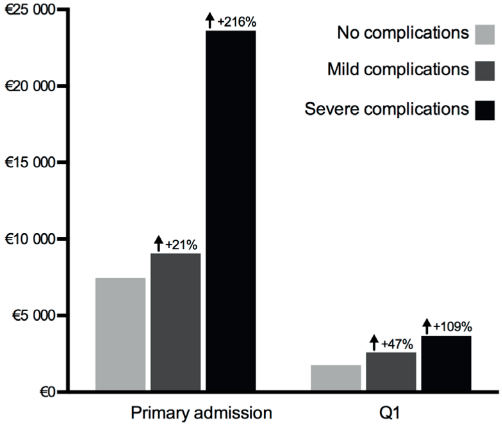


Figure 2. Increase in costs for colorectal cancer patients with a complicated course
Average costs per patient of primary admission and Q1 (=first 90 days after discharge). Arrow represents difference as compared to 'no complications'.

Major complications were associated with an even higher increase (= 196%) in costs. Using the mixed model with hospitals as random effects costs significantly increased with €17906 (CI €17189: €18623, $p < 0.001$). This increase mainly depended on higher costs in the categories intensive care, ward and operation (Table 2A).
Patients suffering minor complications and major complications had longer total operation time, hospital stay and Intensive Care stay (Table 2B).

Table 2a. Detailed overview of costs of complications

	No complication	Minor complication	Major complication
n	4527	819	1422
Categories			
Operation	€ 3492	€ 3674	€ 4912
Ward	€ 3653	€ 4957	€ 8593
Intensive care	€ 670	€ 1025	€ 9167
Radiology	€ 148	€ 239	€ 558
Laboratory	€ 480	€ 609	€ 1749
Consulting	€ 338	€ 453	€ 630
Materials	€ 107	€ 185	€ 550
Other	€ 339	€ 505	€ 1128
Total	**€ 9226**	**€ 11648**	**€ 27287**

Table 2b. Attributers of costs

	No complication	Minor complication	Major complication
n	4527	819	1422
Attributers			
Operation time (hour)	3.01	3.22	3.32
Hospital LOS (days)*	10.29	13.97	28.60
IC LOS (days)	0.40	0.59	4.95

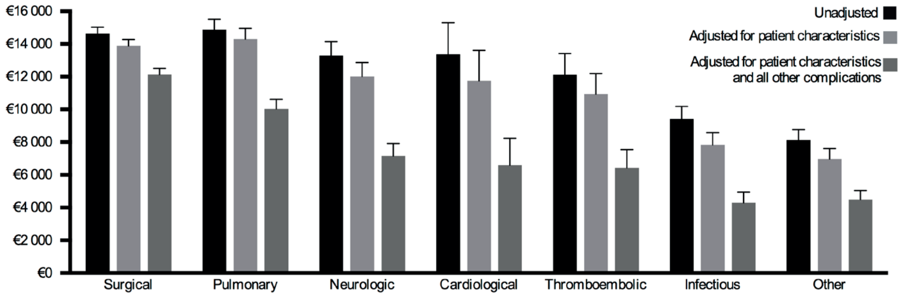
Data is shown from day of primary surgery up to 90 days after discharge (therefore costs/ hours/ days associated with re-hospitalizations or re-operations up to 90 days after discharge are included). Abbreviations: LOS, length of stay; IC, intensive care. * Including IC days.

Specific complications

All types of complications were associated with large increase in hospital costs, compared with those without complications. Most common complications were surgical complications (n = 1347, 19.9%). The largest increase in unadjusted costs was seen for pulmonary complications (n = 465, €14873, CI €13603: €16144, p < 0.001). After risk-adjustment for patient characteristics pulmonary complications were still associated with the largest attributable costs as well (=€14308, CI €13050: €15565, p < 0.001). After risk-adjustment, for patient characteristics and for other complications, surgical complications were associated with the largest attributable costs (= €12131, CI €11398: €12863, p < 0.001) (Figure 3). In detail, patients suffering from an anastomotic leakage (n= 468, €33486) were almost 3 times more expensive than patients without an anastomotic leakage (n = 6314, €11821).

Patients' characteristics associated with clinical and financial outcomes

Independent from other risk factors, the strongest association with severe complications was seen for ASA IV-V (OR 3.998, CI 2.582:6.188, p < 0.001), urgent resections (OR 1.886, CI 1.554:2.289, p < 0.001) and 5 x 5 Gray preoperative radiotherapy (OR 1.809, CI 1.318:2.482, p < 0.001). Independent from other risk factors, the strongest association with increased costs was seen for ASA IVV patients (RC €7264, CI €4355: €10172, p < 0.001), patients with synchronous tumors (RC €3302, CI €1388: €5215, p = 0.001) and ASA III patients (RC €3295, CI €2327: €4266, p < 0.001) (Figure 4).



			Attributable increase with complication*								
Complication			**Unadjusted**			**Adjusted for patient characteristics**			**Adjusted for patient characteristics and all other complications**		
	n			95% CI			95% CI			95% CI	
Surgical	1347	19.9%	**€ 14638**	€ 13875	€ 15401	**€ 13894**	€ 13142	€ 14646	**€ 12131**	€ 11398	€ 12863
Pulmonary	465	6.9%	**€ 14873**	€ 13603	€ 16144	**€ 14308**	€ 13050	€ 15565	**€ 10024**	€ 8858	€ 11189
Cardiological	271	4.0%	**€ 13290**	€ 11621	€ 14959	**€ 12014**	€ 10353	€ 13675	**€ 7156**	€ 5660	€ 8653
Thromboembolic	52	0.8%	**€ 13363**	€ 9576	€ 17151	**€ 11739**	€ 8073	€ 15404	**€ 6598**	€ 3374	€ 9823
Neurologic	117	1.7%	**€ 12120**	€ 9578	€ 14662	**€ 10931**	€ 8454	€ 13408	**€ 6424**	€ 4233	€ 8615
Infectious	353	5.2%	**€ 9424**	€ 7940	€ 10908	**€ 7843**	€ 6389	€ 9297	**€ 4290**	€ 2998	€ 5583
Other	502	7.4%	**€ 8124**	€ 6860	€ 9389	**€ 6977**	€ 5739	€ 8215	**€ 4485**	€ 3389	€ 5582

Figure 3. Relationship of complications after colorectal surgery to unadjusted and adjusted hospital costs Attributable increase in costs with complication is shown. In graph std. error is shown. *P-values for all attributable costs were <0.001.

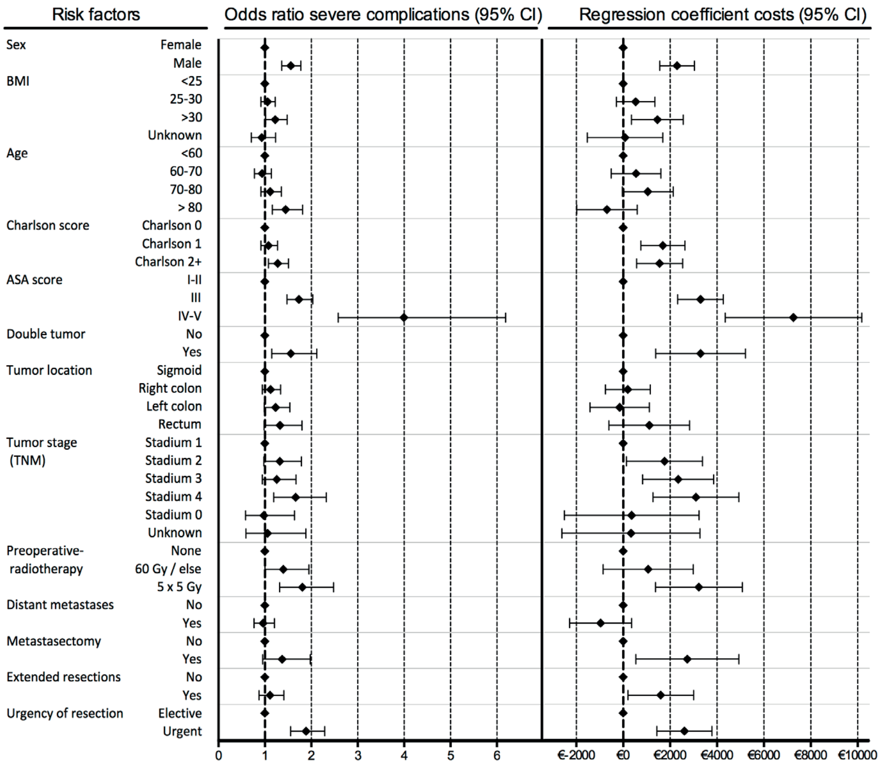


Figure 4. Risk factors associated with severe complications and costs of those severe complications
Risk factors (patient characteristics listed in Table 1) associated with severe complications and total costs (primary admission and Q1) were investigated by using multivariate regression models with hospitals as random effects. Abbreviations: BMI, Body Mass Index; ASA, American Society of Anesthesiologists risk score; Left colon, including transverse colon; TNM, Classification of Malignant Tumors; Gy, gray.

DISCUSSION

This is the first European multicenter study providing a detailed estimate of hospital costs associated with adverse events in colorectal cancer surgery. In addition this report shows that almost a quarter of hospitals budget for colorectal cancer surgery is spend on a relatively small percentage of patients and almost a third of hospitals budget is spend on treating complications. Our report highlights that risk factors for severe complications are associated with high costs as well. Since more and more pressure is being exerted on health care providers to simultaneously improve quality and reduce the costs of the provided care, the conclusions based on this article should catalyze the development of targeted quality improvement programs.

Complications after colorectal cancer surgery in this report were common and occurring after 33% of the procedures performed. In the studied population, 12% had mild complications and 21% had severe complications which is comparable with an earlier study using data from the American College of Surgeons National Surgical Quality Improvement Program (29% of adverse events) [10]. The average costs of colorectal patients (and their complications) in our study are consistent with earlier studies as well[3], however we provide this evidence based on detailed clinical and financial data. In addition to the existing literature, this study has some major advantages. Our results are based on multi-center data, which gives a more comprehensive perspective as publication bias of individual 'well performing' hospitals [3-5] is avoided. Instead of using insurance claim data to calculate costs [7,9] this study was performed from a hospitals perspective using TD-ABC methodology, which is a superior method for measuring and understanding costs [17,18]. Clinical data was retrieved from the detailed DSCA dataset, therefore enabling accurate risk-adjustment [13]. Moreover, since the DSCA is a population-based registry, the data was not hampered by overrepresentation of a specific group of patients (Table 1). In contrast, two recent multi-center studies from the United States analyzing costs of complications retrieved their data from Veterans Affairs hospitals [6,8]. Almost 95% of their analyzed patients were male which is a major risk factor for complications itself [23] and consequently a risk factor for increased costs (Figure 4). Surgical complications were most common after colorectal cancer surgery and were, independent from differences in patient characteristics and other complications, associated with the highest increase in hospital costs (Figure 3). After adjustment for other complications, strongest decrease in additional costs was seen for thromboembolic complications (reduction of €5141). This suggests that thromboembolic complications often occur at the same time with other complications.

To create more insight in the relation between severe complications and the costs of severe complications we analyzed risk factors for severe complications and hospital costs. For almost every risk factor associated with the development of severe complications, a similar trend was seen for developing high hospital costs. This means that patients with a high risk for complications are a risk for generating high hospital costs as well. ASA IV-V, short course radiotherapy, ASA III and TNM-stage 4 were top-5 risk factors for both developing severe complications as well as high hospital costs (Figure 4). Remarkable is the inverse relationship between severe complications and costs for patients older than 80 years. As compared to patients under 60 years and independently from other risk factors, octogenarians were associated with a significant increased risk for developing severe complications (OR 1.449, CI 1.158:1.812, p = 0.001) though associated with a decrease in hospital costs (RC €-691, CI €-1984: €601, p = 0.29). Nevertheless, when looking at unadjusted averages, octogenarians were still associated with slightly higher costs as compared to patients under 60 years (data not shown). This means that high age itself (> 80 years) is not associated with higher hospital costs though comorbidities (or other patient characteristics) of octogenarians are.

Limitations

This study has some limitations. First of all one might argue that in their attempts to achieve lower complication rates, participants might not register patients with complications. Also under-registration of complications themselves might happen, in order to achieve lower complication rates. However, registration of surgical colorectal cancer patients in the DSCA is a National Performance Indicator [12], resulting in high completeness of the DSCA as compared to the National Cancer Registry [11]. We also looked in detail to hospital costs of patients without complications; outliers in costs were hardly seen, making this under-registration less plausible. Second, some costs are not likely to be affected by a reduction of complications in the short term, like overhead costs and staffing. Therefore, assuming a direct relationship between a single complication and costs may not be appropriate. Third, a direct relationship between the introduction of clinical auditing for colorectal cancer surgery in the Netherlands and the marked reduction of complications can hardly be proven. The introduction of laparoscopic surgery in many hospitals, or other secular trends registered in the audit or not, may have lead to an improvement in quality of care itself. Nevertheless, without availability of key data on outcomes, health care organizations are flying blind in deciding what should be targets for quality improvement initiatives. Moreover, combining key outcome data with accurate financial outcomes should be the cornerstone of developing an affordable health care system [18].

The business case

An addition to studies from the United States describing costs of complications after surgery [5,6,8] is the specific selection of colorectal cancer patients analyzed in this study. Those earlier studies analyzed a broad variation of general (and/or vascular) surgical procedures, which makes their conclusions harder to implement for targeted improvement programs. As described by Schilling et al. colon surgery is associated with a disproportional share of complications in general surgery. Representing only 10% of the analyzed procedures in their study, colon surgery was responsible for almost 25% of the complications [10]. Obviously, a decline in complication rates after colorectal surgery will be of most benefit to the patients, however one might argue that a business case for quality improvement can be made for hospitals as well [24]. Described by an earlier study of our group, severe complication rates after implementation of a nationwide colorectal surgical audit dropped from 25% in 2010 to 20% in 2012 [2]. If a hospital performed an average of 100 colorectal cancer procedures per year and had an average severe complication rate in 2010 of 25%, an annual reduction in severe complications of 10% may lead to a saving of €120000 in 2012 as compared to 2010 (1 major complication is associated with €16059 of additional costs, Supplemental Table 2). A reduction of complications can only be achieved when key data regarding clinical outcomes is available, identifying areas for targeted quality improvement programs. Since this is a cost and time consuming exercise [25] we also calculated the costs for participation in the DSCA for this exampled hospital (Supplemental Table 3). If yearly costs for participation (€13350) were incorporated in the analysis as well, overall profit after three years for this single hospital would be more then €80000 (Supplemental Table 2). This should be a strong incentive for healthcare providers to support and develop targeted quality improvement programs in order to simultaneously improve quality of healthcare and reduce costs.

Future perspectives

A recent study from the United States [26] described that under some payers the occurrence of surgical complications was associated with higher hospital contribution margins, therefore providing a perverse stimulus for healthcare providers. The Dutch healthcare system does not have different reimbursements for patients with or without complications, and therefore reducing complications in Dutch hospitals will directly benefit hospitals finances. A solution to overcome contra-productive reimbursement systems [26], might be the introduction of bundled payments that are tied to overall care for a medical condition [18]. Well-designed bundled payments encourage teamwork and should include severity adjustments for more complex patients (in order to compensate for potential higher costs as seen in Figure 4). Ideally, these bundled payments should hold the provider financial responsible for avoidable complications, preferable for a long period (e.g. 1 or 2 year after surgery), resulting in a strong incent to improve (long-term) outcomes for patients [18]. Providers might benefit from improving efficiency while maintaining or improving the value for patients, as seen in certain regions in Sweden [27].

CONCLUSIONS

This study shows that besides patients health care providers suffer from complications as well: tremendous increase in costs is seen for colorectal cancer patients with a complicated postoperative recovery. Key data on clinical outcomes is necessary to measure value and to identify patients at risk. Admitting that surgical audits are time and costs consuming exercises, our business case shows that investments made to develop targeted quality improvement programs will pay of eventually. Therefore conclusions based on this study should be an impetus for healthcare providers to develop and maintain targeted quality improvement programs.

REFERENCES

1. Birkmeyer JD, Gust C, Dimick JB, Birkmeyer NJ, Skinner JS. Hospital quality and the cost of inpatient surgery in the United States. *Annals of surgery.* 2012;255(1):1-5.
2. J.A. Govaert et al. 'Improving Quality and Reducing Costs in Colorectal Cancer Surgery', presented at the 34th Congress of the European Society of Surgical Oncology, Liverpool, October 2014
3. Zoucas E, Lydrup ML. Hospital costs associated with surgical morbidity after elective colorectal procedures: a retrospective observational cohort study in 530 patients. *Patient safety in surgery.* 2014;8(1):2.
4. Vonlanthen R, Slankamenac K, Breitenstein S, et al. The impact of complications on costs of major surgical procedures: a cost analysis of 1200 patients. *Annals of surgery.* 2011;254(6):907-913.
5. Dimick JB, Chen SL, Taheri PA, Henderson WG, Khuri SF, Campbell DA, Jr. Hospital costs associated with surgical complications: a report from the private-sector National Surgical Quality Improvement Program. *J Am Coll Surg.* 2004;199(4):531-537.
6. Vaughan-Sarrazin M, Bayman L, Rosenthal G, Henderson W, Hendricks A, Cullen JJ. The business case for the reduction of surgical complications in VA hospitals. *Surgery.* 2011;149(4):474-483.
7. Short MN, Aloia TA, Ho V. The influence of complications on the costs of complex cancer surgery. *Cancer-Am Cancer Soc.* 2014;120(7):1035-1041.
8. Carey K, Stefos T, Shibei Z, Borzecki AM, Rosen AK. Excess costs attributable to postoperative complications. *Medical care research and review : MCRR.* 2011;68(4):490-503.
9. Encinosa WE, Hellinger FJ. The impact of medical errors on ninety-day costs and outcomes: an examination of surgical patients. *Health services research.* 2008;43(6):2067-2085.
10. Schilling PL, Dimick JB, Birkmeyer JD. Prioritizing quality improvement in general surgery. *Journal of the American College of Surgeons.* 2008;207(5):698-704.
11. Dutch Surgical Colorectal Audit.
12. Van Leersum NJ, Snijders HS, Henneman D, et al. The Dutch surgical colorectal audit. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2013;39(10):1063-1070.
13. Kolfschoten NE, Marang van de Mheen PJ, Gooiker GA, et al. Variation in case-mix between hospitals treating colorectal cancer patients in the Netherlands. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2011;37(11):956-963.
14. Performation. http://www.performation.com.
15. Klarenbeek BR, Coupe VM, van der Peet DL, Cuesta MA. The cost effectiveness of elective laparoscopic sigmoid resection for symptomatic diverticular disease: financial outcome of the randomized control Sigma trial. *Surgical endoscopy.* 2011;25(3):776-783.
16. Performation was former known as TRAG Performance Intelligence, Zeist, The Netherands
17. Kaplan RS, Anderson SR. Time-driven activity-based costing. *Harvard business review.* 2004;82(11):131-138, 150.
18. Porter ME, Lee TH. The Strategy That Will Fix Health Care. *Harvard business review.* 2013;91(12):24-24.

19. Kolfschoten NE, van Leersum NJ, Gooiker GA, et al. Successful and safe introduction of laparoscopic colorectal cancer surgery in Dutch hospitals. *Annals of surgery.* 2013;257(5):916-921.
20. Henneman D, van Leersum NJ, Ten Berge M, et al. Failure-to-rescue after colorectal cancer surgery and the association with three structural hospital factors. *Ann Surg Oncol.* 2013;20(11):3370-3376.
21. McCulloch CE, Searle, Shayle R. *Generalized, Linear, and Mixed Models.* 1st ed. New York: John Wiley & Sons; 2001.
22. Lindsey JK, Jones B. Choosing among generalized linear models applied to medical data. *Statistics in medicine.* 1998;17(1):59-68.
23. Kirchhoff P, Clavien PA, Hahnloser D. Complications in colorectal surgery: risk factors and preventive strategies. *Patient safety in surgery.* 2010;4(1):5.
24. Dimick JB, Weeks WB, Karia RJ, Das S, Campbell DA, Jr. Who pays for poor surgical quality? Building a business case for quality improvement. *Journal of the American College of Surgeons.* 2006;202(6):933-937.
25. Hammermeister K. The National Surgical Quality Improvement Program: learning from the past and moving to the future. *American journal of surgery.* 2009;198(5 Suppl):S69-73.
26. Eappen S, Lane BH, Rosenberg B, et al. Relationship between occurrence of surgical complications and hospital finances. *Jama.* 2013;309(15):1599-1606.
27. Porter ME, Marks C, Landman ZC. OrthoChoice: Bundled Payments in the County of Stockholm. Harvard Business School. 2014 Product #:714515-PDF-ENG.

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

Supplemental Table 2. The business case

	2010	**2011**	**2012**	**Total**
Yearly cost of registration*	€ 13350	€ 13350	€ 13350	€ 40050
Severe complication rate (%)	25,0%	22,5%	20,0%	n/a
Potential cost saving (€)**	n/a	€ 40148	€ 80295	€ 120443
Net saving	-€ 13350	€ 26798	€ 66945	€ 80393

Potential cost saving for one hospital performing 100 colorectal cancer procedures a year. * See supplemental table 3. ** As compared to 2010 and based on €16059 of additional costs of 1 severe complication.

Supplemental Table 3. Yearly costs of clinical auditing in 2012

		Cost price	n	total
Fixed costs	Yearly hospital fee*	€ 3000	1	€ 3000
	Monthly hospital fee*	€ 300	12	€ 3600
Variable costs	Fee per patient*	€ 25	100	€ 2500
	Costs of registration**	€ 17	100	€ 1700
	Costs of verification***	€ 26	100	€ 2550
Total costs	Total per patient	€ 134	100	€ 13350

* Costs based on Dutch Surgical Colorectal Audit 2012 fee. ** Based on 30 minutes of registration by a Physician Assistant (year salary €60000). *** Based on 15 minutes of verification by a surgeon (yearly salary €180000).

CHAPTER 5

J.A. Govaert

M. Fiocco

W.A. van Dijk

N.E. Kolfschoten

H.A. Prins

J.W.T. Dekker

R.A.E.M. Tollenaar

P.J. Tanis*

M.W.J.M. Wouters*

* P.J. Tanis and M.W.J.M. Wouters contributed equally to this work

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

Annals of Surgery 2016

On behalf of the Dutch Value Based Healthcare Study Group
B. Lamme, MD, PhD (Albert Schweitzer Ziekenhuis, Dordrecht); D.A. Hess MD, PhD (Antonius ziekenhuis, Sneek); H.J. Belgers, MD (Atrium-Orbis, Heerlen); O.R. Guicherit, MD, PhD (MCH-Bronovo, Den Haag); C. Rosman, MD, PhD (Canisius Wilhelmina Ziekenhuis, Nijmegen); Prof H.J.T. Rutten, MD, PhD (Catharina Hospital, Eindhoven/ Maastricht University Medical Hospital, Maastricht); F.N.L. Versluijs-Ossewaarde. MD (Diaconessenhuis, Meppel); E.S. Van der Zaag, MD, PhD (Gelre Ziekenhuizen, Apeldoorn); L.N.L. Tseng, MD (Groene Hart Ziekenhuis, Gouda); E.J.R. de Graaf, MD, PhD (IJsselland Hospital, Capelle aan den Ijssel); W.J. Vles, MD, PhD (Ikazia Ziekenhuis, Rotterdam); E.G.J.M. Pierik, MD, PhD (Isala Kliniek, Zwolle); H.A. Prins, MD, PhD (Jeroen Bosch Ziekenhuis, Den Bosch); P.H.M. Reemst, MD (Máxima Medisch Centrum, Veldhoven); E.C.J. Consten, MD, PhD (Meander Medisch Centrum, Amersfoort); S.A. Koopal, MD PhD (Medisch Centrum Leeuwarden, Leeuwarden); P.A. Neijenhuis, MD, ScS (Alrijne Ziekenhuis, Leiderdorp); G.H.H. Mannaerts, MD, PhD (Sint Franciscus Gasthuis, Rotterdam); A.B. Smits, MD (St. Antonius Ziekenhuis, Nieuwegein); D.H.C. Burger, MD (Elisabeth-Tweesteden Ziekenhuis, Tilburg); M.G.A. van IJken, MD, PhD (Van Weel-Bethesda Ziekenhuis, Dirksland); P. Poortman, MD, PhD (Waterlandziekenhuis, Purmerend); M.J.P.M. Govaert, MD (Westfriesgasthuis, Hoorn); W.A. Bleeker, MD, PhD (Wilhelmina Hospital Assen); F.C. Den Boer, MD, PhD (Zaans Medical Center); F. Wit, MD (Ziekenhuis Tjongerschans, Heerenveen); Ph. M. Kruyt, MD (Ziekenhuis Gelderse Vallei, Ede); A. Mearadji, MD, PhD (Bravis Ziekenhuis, Bergen op Zoom); J.T. Heikens, MD, PhD (Ziekenhuis Rivierenland, Tiel)

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).

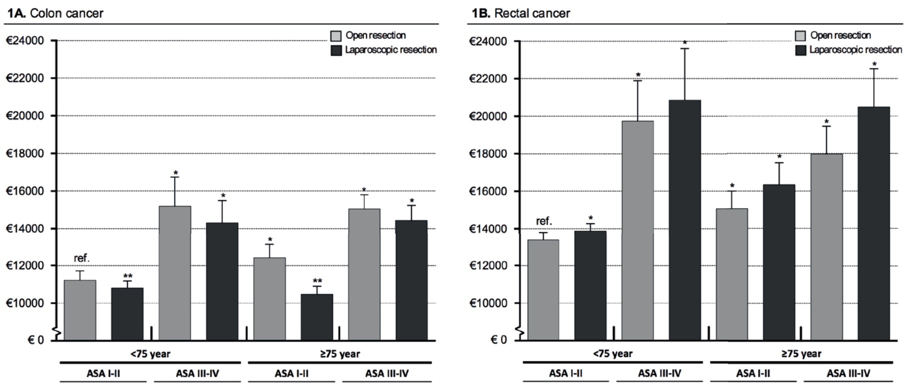


Figure 1. Total costs of colon and rectum cancer resections stratified by sub-group
1A. Colon cancer
1B**.** Rectal cancer
Abbreviations: ASA, American Society of Anesthesiologists classification. Error bar shows standard error of the mean. * Significant more expensive (p<0.05.) as compared to reference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

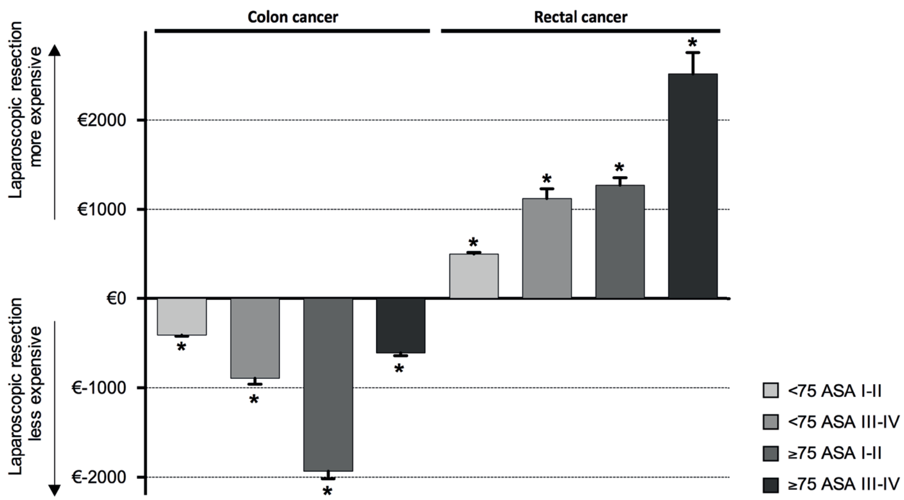


Figure 2. Cost difference between laparoscopic and open resections stratified by sub-group Abbreviations: ASA, American Society of Anesthesiologists classification. Error bar shows 95% upper confidence interval. * Significant difference between open and laparoscopic resections (p<0.001).

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.

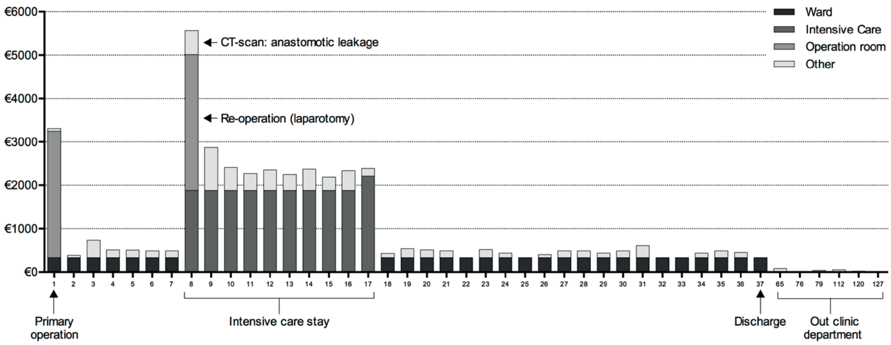
REFERENCES

1. Stevenson AR, Solomon MJ, Lumley JW, et al. Effect of Laparoscopic-Assisted Resection vs Open Resection on Pathological Outcomes in Rectal Cancer: The ALaCaRT Randomized Clinical Trial. *Jama.* 2015;314(13):1356-1363.

2. Fleshman J, Branda M, Sargent DJ, et al. Effect of Laparoscopic-Assisted Resection vs Open Resection of Stage II or III Rectal Cancer on Pathologic Outcomes: The ACOSOG Z6051 Randomized Clinical Trial. *Jama.* 2015;314(13):1346-1355.
3. Kuhry E, Schwenk W, Gaupset R, Romild U, Bonjer J. Long-term outcome of laparoscopic surgery for colorectal cancer: a cochrane systematic review of randomised controlled trials. *Cancer Treat Rev.* 2008;34(6):498-504.
4. Schwenk W, Haase O, Neudecker J, Muller JM. Short term benefits for laparoscopic colorectal resection. *Cochrane Database Syst Rev.* 2005(3):CD003145.
5. Bartels SA, Vlug MS, Hollmann MW, et al. Small bowel obstruction, incisional hernia and survival after laparoscopic and open colonic resection (LAFA study). *The British journal of surgery.* 2014;101(9):1153-1159.
6. Kolfschoten NE, van Leersum NJ, Gooiker GA, et al. Successful and safe introduction of laparoscopic colorectal cancer surgery in Dutch hospitals. *Annals of surgery.* 2013;257(5):916-921.
7. van der Pas MH, Haglind E, Cuesta MA, et al. Laparoscopic versus open surgery for rectal cancer (COLOR II): short-term outcomes of a randomised, phase 3 trial. *Lancet Oncol.* 2013;14(3):210-218.
8. Braga M, Vignali A, Zuliani W, Frasson M, Di Serio C, Di Carlo V. Laparoscopic versus open colorectal surgery: cost-benefit analysis in a single-center randomized trial. *Annals of surgery.* 2005;242(6):890-895, discussion 895-896.
9. Braga M, Frasson M, Zuliani W, Vignali A, Pecorelli N, Di Carlo V. Randomized clinical trial of laparoscopic versus open left colonic resection. *The British journal of surgery.* 2010;97(8):1180-1186.
10. Janson M, Bjorholt I, Carlsson P, et al. Randomized clinical trial of the costs of open and laparoscopic surgery for colonic cancer. *The British journal of surgery.* 2004;91(4):409-417.
11. Braga M, Frasson M, Vignali A, Zuliani W, Capretti G, Di Carlo V. Laparoscopic resection in rectal cancer patients: outcome and cost-benefit analysis. *Diseases of the colon and rectum.* 2007;50(4):464-471.
12. Buskens C. Clinical study designs and corresponding levels of evidence: time to redefine? *Colorectal disease : the official journal of the Association of Coloproctology of Great Britain and Ireland.* 2015;17(9):745-746.
13. Dreyer NA, Garner S. Registries for robust evidence. *Jama.* 2009;302(7):790-791.
14. Gietelink L, Wouters MW, Bemelman WA, et al. Reduced 30-Day Mortality After Laparoscopic Colorectal Cancer Surgery: A Population Based Study From the Dutch Surgical Colorectal Audit (DSCA). *Annals of surgery.* 2016;264(1):135-140.
15. Govaert JA, van Dijk WA, Fiocco M, et al. Nationwide Outcomes Measurement in Colorectal Cancer Surgery: Improving Quality and Reducing Costs. *Journal of the American College of Surgeons.* 2016;222(1):19-29 e12.
16. Srebniak MI, Diderich KE, Govaerts LC, et al. Types of array findings detectable in cytogenetic diagnosis: a proposal for a generic classification. *European journal of human genetics : EJHG.* 2014;22(7):856-858.
17. Van Leersum NJ, Snijders HS, Henneman D, et al. The Dutch surgical colorectal audit. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2013;39(10):1063-1070.
18. Performation. http://www.performation.com.

19. Kaplan RS, Anderson SR. Time-driven activity-based costing. *Harvard business review.* 2004;82(11):131-138, 150.
20. Porter ME, Lee TH. The Strategy That Will Fix Health Care. *Harvard business review.* 2013;91(12):24-24.
21. Mercier G, Naro G. Costing hospital surgery services: the method matters. *PloS one.* 2014;9(5):e97290.
22. Doat S, Thiebaut A, Samson S, Ricordeau P, Guillemot D, Mitry E. Elderly patients with colorectal cancer: treatment modalities and survival in France. National data from the ThInDiT cohort study. *Eur J Cancer.* 2014;50(7):1276-1283.
23. Bowel cancer screening programme by the Dutch Minister of Health, Welfare and Sport http://www.rivm.nl/en/Topics/B/Bowel_cancer_screening_programme. Accessed 2016-06-22.
24. Altman DG. *Practical Statistics for Medical Research.* Chapman and Hall/ CRC; 1991.
25. Hilgert N, Huentelman MJ, Thorburn AQ, et al. Phenotypic variability of patients homozygous for the GJB2 mutation 35delG cannot be explained by the influence of one major modifier gene. *European journal of human genetics : EJHG.* 2009;17(4):517-524.
26. Crawshaw BP, Chien HL, Augestad KM, Delaney CP. Effect of laparoscopic surgery on health care utilization and costs in patients who undergo colectomy. *JAMA surgery.* 2015;150(5):410-415.
27. Delaney CP, Chang E, Senagore AJ, Broder M. Clinical outcomes and resource utilization associated with laparoscopic and open colectomy using a large national database. *Annals of surgery.* 2008;247(5):819-824.
28. Keller DS, Champagne BJ, Reynolds HL, Jr., Stein SL, Delaney CP. Cost-effectiveness of laparoscopy in rectal cancer. *Diseases of the colon and rectum.* 2014;57(5):564-569.
29. Son HJ, Lee HY, Park JW, Choi HS, Jeong SY, Oh JH. Cost-comparison of laparoscopic and open surgery for mid or low rectal cancer after preoperative chemoradiotherapy: data from a randomized controlled trial. *World journal of surgery.* 2013;37(1):214-219.
30. Franks PJ, Bosanquet N, Thorpe H, et al. Short-term costs of conventional vs laparoscopic assisted surgery in patients with colorectal cancer (MRC CLASICC trial). *Br J Cancer.* 2006;95(1):6-12.
31. Jensen CC, Prasad LM, Abcarian H. Cost-effectiveness of laparoscopic vs open resection for colon and rectal cancer. *Diseases of the colon and rectum.* 2012;55(10):1017-1023.
32. Park JS, Kang SB, Kim SW, Cheon GN. Economics and the laparoscopic surgery learning curve: comparison with open surgery for rectosigmoid cancer. *World journal of surgery.* 2007;31(9):1827-1834.
33. Delaney CP, Kiran RP, Senagore AJ, Brady K, Fazio VW. Case-matched comparison of clinical and financial outcome after laparoscopic or open colorectal surgery. *Annals of surgery.* 2003;238(1):67-72.
34. Govaert JA, Fiocco M, van Dijk WA, et al. Costs of complications after colorectal cancer surgery in the Netherlands: Building the business case for hospitals. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2015;41(8):1059-1067.

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

CHAPTER 6

Y.T.K. van der Linden*

J.A. Govaert *

M. Fiocco

W.A. van Dijk

D.J. Lips

H.A. Prins

* Y.T.K. van der Linden and J.A. Govaert contributed equally to this work

SINGLE CENTER COST ANALYSIS OF SINGLE-PORT AND CONVENTIONAL LAPAROSCOPIC SURGICAL TREATMENT IN COLORECTAL MALIGNANT DISEASES

International Journal of Colorectal Disease 2016

ABSTRACTS

Background and purpose

Single-port laparoscopy (SPL) is a relatively new technique, used in various procedures. There is limited knowledge about the cost effectiveness and the learning curve of this technique. The primary aim of this study was to compare hospital costs between SPL and conventional laparoscopic resections (CLR) for colorectal cancer; the secondary aim was to identify a learning curve of SPL.

Methods

All elective colorectal cancer SPL and CLR performed in a major teaching hospital between 2011 and 2012 that were registered in the Dutch Surgical Colorectal Audit were included (n = 267). The economic evaluation was conducted from a hospital perspective, and costs were calculated using time-driven activity-based costing methodology up to 90 days after discharge. When looking at SPL only, the introduction year (2011) was compared to the next year (2012).

Results

SPL (n = 78) was associated with lower mortality, lower reintervention rates, and more complications as compared to CLR (n = 189); however, none of these differences were statistically significant. A significant shorter operating time was seen in the SPL. Total costs were higher for SPL group as compared to CLR; however, this difference was not statistically significant. For the SPL group, most clinical outcomes improved between 2011 and 2012; moreover, total hospital costs for SPL in 2012 became comparable to CLR.

Conclusion

No significant differences in financial outcomes between SPL and CLR were identified. After the introduction period, SPL showed similar results as compared to CLR. Conclusions are based on a small single-port group and the conclusions of this manuscript should be an impetus for further research.

INTRODUCTION

Laparoscopic surgery for colorectal cancer results in faster recovery, reduced morbidity, shorter length of hospital stay, and less postoperative pain, with similar oncological and longterm outcomes as compared to open surgery [1-6]. There are several studies analyzing costs between open and laparoscopic colorectal surgery; however, no consensus is reached about this topic; some studies show cost neutrality, while others favor open or laparoscopic surgery [7-10]. Advanced minimal invasive techniques like single-port laparoscopy (SPL) are developed in order to reduce surgical trauma and/or to provide better cosmetic results and are used in both benign diseases and malignant diseases [11-13]. In literature, there are many studies addressing safety and feasibility of SPL as compared to conventional laparoscopic resection (CLR) for colorectal cancer. However, studies on cost-effectiveness of SPL are scarce [14].

In 2010, the gastrointestinal surgeons of the Jeroen Bosch Hospital started with the introduction of the single-port technique for less complex abdominal procedures [15,16]. This resulted in the first single-port laparoscopic colorectal resection for cancer in 2011. Nowadays, SPL is becoming a standard of care for multiple procedures in our institution.

The objective of this study was to compare the hospital costs of SPL with CLR for elective colorectal cancer procedures. The secondary aim was to analyze a possible learning curve in SPL technique by analyzing operating times, complication rates, and hospital costs between the first (2011) and the second (2012) years.

MATERIALS AND METHODS

Clinical data

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. Patients undergoing an elective

laparoscopic resection in the studied hospital were selected if the operation was performed between January 1, 2011, and December 31, 2012, and registered in the DSCA before December 1, 2013. A detailed description of the DSCA has been published recently [17,18].
Minimal data requirements to consider a patient eligible for matching with the financial dataset was information on tumor location, date of surgery, and mortality status.

Financial data

The economic evaluation was conducted from a hospital perspective. As such, only Bin-hospital^ costs were considered. Costs were taken into account from the day of initial surgery till discharge (=primary admission) and the first 90 days after discharge (=Q1). Resource utilization at patient level was extracted from the Hospital Information System. 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 [19,20]. Costs were calculated using time-driven activity-based costing (TD-ABC) methodology [21] which is an advanced method for understanding hospitals costs. [22] Cost price calculations are standardized by Performation, and therefore, uniformity in methodology exists over the years. The most recent cost price model (2012) was used for both years (2011 and 2012) to avoid differences due to inflation or due to the different models themselves. Different activities are grouped into eight categories as shown in Supplemental Table 1. All activities consisted of direct costs (e.g., personnel, material. and equipment) and indirect costs. For example, direct costs for an inpatient day (category “ward”) consisted of (a) personnel as salary of ward nurses and administrative personnel, (b) material costs as bed linen and bandages, and (c) depreciation of equipment such as beds and ward inventory. Examples of indirect costs are costs related to information technology, building depreciation, cleaning, catering, etc. Specialists’ fees, medication costs, and costs for dialyses were excluded since registration of these parameters was not uniform in both years making equal comparison impossible.

Match

Unique patient identification number was used to match patients registered in the DSCA to the financial database (279 patients). Laparoscopic resections in an urgent setting (n = 12) were excluded, resulting in 267 eligible patients for analysis.

Definitions

CLR was defined as any procedure that started with the intention to resect the tumor using conventional laparoscopic techniques. SPL was defined as any procedure that started with the intention to resect the tumor laparoscopic using a single port. The choice between the two different techniques (CLR or SPL) was made by the preference of the surgeon and the patient. In the studied hospital, there were two trained single-port laparoscopic surgeons; all SPL procedures were performed by at least one of these two surgeons. Laparoscopic trained surgeons, a total of four including in some cases the two trained SPL surgeons, performed the CLR procedures. In both groups, residents participated. However, the first surgeon was always a trained surgeon.

Primary outcome measures for quality of health care were (1) postoperative mortality, defined as in-hospital or 30-day mortality, and (2) major morbidity, defined as an in-hospital or 30-day adverse outcome with serious consequences leading to mortality, a reintervention (percutaneous or operative), or a postoperative hospital stay of at least 14 days. Secondary outcome measures occurring in-hospital or within 30 days after resection were (3) any complication, (4) prolonged length of stay, defined as a primary admission stay of more than 14 days, (5) reintervention (percutaneous or operative), (6) anastomotic leakage, (7) R1/R2 resection, (8) resections in whom less than 10 lymph nodes (conform Dutch guidelines)/12 lymph nodes (conform international TNM guidelines) were retrieved, and (9) conversion to open surgery. Primary financial measure was (10) total costs per patient (=primary admission up to 90 days after discharge). Secondary financial outcomes were (11) duration of primary operation, (12) costs of primary operation, and (13) total costs by category (=primary admission up to 90 days after discharge by category as mentioned in Supplemental Table 1).

Analysis

Chi-squared test was used to investigate differences between patients' characteristics in the two groups under study (Table 1). Absolute clinical and financial outcomes were presented unadjusted. To investigate the effect of CLR and SPL on the outcome of interest, multivariate logistic regression and linear regression were performed [23,24]. To investigate the effect of year of surgery for the SPL group, multivariate logistic regression and linear regression models were employed. For multivariate logistic regression models, an interaction term between year and type of surgery was fitted. Since this is a single-center study, we could not use extended risk adjustment for all clinical outcomes due to the small number of events for some outcomes. For those outcomes (mortality, reintervention, anastomotic leakage, R1/R2 resection, and conversion to open surgery), odds ratios without risk adjustment were computed. Patient characteristics used for the regression models were sex, body mass index (BMI ≥30), age (≥70 years), comorbidity (Charlson score ≥2) [25], American Society of Anesthesiologists classification (ASA ≥3), location of tumor (colon or rectum), stage of tumor (TNM stage ≥3), and preoperative radiotherapy (1).
Statistical analyses were performed using SPSS (version 20; IBM) and R (version 18). Confidence intervals (CI) were stated at 95 %.

RESULTS

No significant differences in patient characteristics were identified between the CLR group (n=189) and SPL group (n=78), see Table 1 for patients characteristics.

Clinical outcomes

Percentage of patients in whom less than 12 lymph nodes were retrieved was significantly lower for SPL. Moreover, SPL was associated with lower mortality rate, lower reintervention rate, lower anastomotic leakage rate, lower R1/R2 resection rate, lower percentage of patients in whom less than 10 lymph nodes were retrieved, and lower conversion rate, although these differences did not reach statistical significance. SPL was associated with higher major morbidity, complications, and prolonged length of stay (no significant differences) (Table 2).

Table 1. Patient, tumor and treatment characteristic for conventional laparoscopic resection (CLR) and single-port laparoscopy (SPL)

		CLR		SPL		p-value
		n	%	n	%	
Total		189	-	78	-	
Sex	Male	108	57%	43	55%	0.763
BMI	≥30 kg/m^2	33	18%	10	13%	0.363
Age	≥70 years	96	51%	41	53%	0.792
Charlson score	Charlson ≥2	33	18%	12	15%	0.680
ASA score	ASA ≥III	23	12%	7	9%	0.452
Tumor location	Colon	139	74%	52	67%	0.257
	Rectum	50	27%	26	33%	
Tumor stage (TNM)	Stadium ≥III	113	65%	43	61%	0.567
Double tumor	Yes	2	2.6%	5	2.6%	0.970
Preoperative radiotherapy	Yes	45	24%	26	33%	0.109

Abbreviations: BMI, Body Mass Index; ASA, American Society of Anaesthesiologists risk score; TNM, Classification of Malignant Tumours; Statistical analyses performed using Chi-square test.

6

Table 2. Clinical outcomes after conventional laparoscopic resection (CLR) and and single-port laparoscopy (SPL)

	CLR	SPL	Odds ratio (95% CI)	p-value
No. patients	189	78		
Mortality	4.2%	1.3%	*0.294 (0.036: 2.390)*	*0.25*
Major morbidity	24.3%	25.6%	0.924 (0.454: 1.879)	0.83
Complication	40.7%	44.9%	1.171 (0.643: 2.132)	0.61
Prolonged length of stay	16.4%	25.6%	1.688 (0.791: 3.602)	0.17
Reintervention	16.4%	10.3%	*0.582 (0.255: 1.331)*	*0.20*
Anastomotic leakage	7.9%	6.4%	*0.795 (0.278: 2.267)*	*0.67*
R1/R2 resection	7.9%	3.8%	*0.464 (0.130: 1.650)*	*0.24*
<10 lymph nodes	28.2%	21.8%	0.469 (0.213: 1.033)	0.06
<12 lymph nodes	48.9%	39.7%	0.477 (0.245: 0.926)	0.03
Conversion to open	8.4%	5.1%	*1.702 (0.546: 5.305)*	*0.36*

Odds ratios and p-values were adjusted for differences in patient characteristics (listed in Table 1) in a logistic regression model. Odds ratios and p-values written in *Italic* were not adjusted for patient characteristics due to the small number of events for those outcomes.

Financial outcomes

SPL was associated with significant shorter operation time. Costs of primary operation were higher as compared to CLR (no significant differences) (Table 3). In all categories, costs of SPL patients were higher as compared to CLR resulting in significantly higher total costs for SPL (Table 4).

Table 3. Primary operation and length of hospital stay after conventional laparoscopic resection (CLR) and single-port laparoscopy (SPL)

	CLR	**SPL**	Delta (95% CI)	p-value
Primary operation costs	€ 1.663	€ 1.781	€-100 (-254: 42)	0.18
Primary operation time	3,48	3,17	0.327 (0.094: 0.544)	0.007
Length of hospital stay	12,06	13,86	-1.48 (-3.73: 0.44)	0.14

Deltas and p-values were adjusted for differences in patient characteristics (listed in Table 1) in a general linear mixed model.

Table 4. Financial outcomes after conventional laparoscopic resection (CLR) and single-port laparoscopy (SPL)

	CLR	**SPL**
Operation	€ 1.881	€ 2.063
Ward	€ 6.692	€ 7.818
ICU	€ 1.823	€ 2.480
Laboratory	€ 664	€ 758
Materials	€ 349	€ 712
Radiology	€ 343	€ 368
Consulting	€ 334	€ 352
Other	€ 653	€ 703
Total costs*	**€ 12.740**	**€ 15.253**

Costs for each category were calculated from primary admission up to 90 days after discharge. *Delta for total costs was adjusted for differences in patient characteristics (listed in Table 1) in a general linear mixed model: Delta €-2125, 95% CI -€4973: €266, p= 0.086.

Time trends

Patient characteristics for SPL surgery were not significantly different between 2011 and 2012 (data not shown). Between 2011 and 2012, the percentage of SPL for colorectal cancer increased from 23.7% to 31.1%. Simultaneously, almost all clinical outcomes improved between 2011 and 2012 (except for mortality and R1/

R2 resection). Since the events in this subgroup of SPL surgery are low, differences in clinical outcomes did not reach statistical significance (except for percentage of patients in whom less than 10 and/or 12 lymph nodes were retrieved, Table 5). Total costs (of primary admission up to 90 days after discharge) and length of hospital stay declined between 2011 and 2012. Moreover, primary operation time for SPL improved significantly (Table 5).

Table 5. Clinical and financial outcomes after SPL between 2011 and 2012: a learning curve?

	2011	**2012**	**Odds ratio (95% CI)**	**p-value**	**2011 vs 2012**
No. Patients (% of yearly total)	28 (23.7%)	50 (31.1%)			+31%
Mortality	0%	2.0%	n/a		n/a
Major morbidity	35.7%	20.0%	0.935 (0.252: 3.471)	0.83	-44%
Complication	57.1%	38.0%	0.629 (0.201: 1.971)	0.43	-33%
Prolonged length of stay	35.7%	20.0%	0.938 (0.243: 3.624)	0.93	-44%
Reintervention	10.7%	10.0%	*0.921 (0.204: 4.202)*	*0.92*	-7%
Anastomotic leakage	7.1%	6.0%	*0.843 (0.130: 5.289)*	*0.84*	-15%
R1/R2 resection	0%	6.0%	n/a		n/a
<10 lymph nodes	35.7%	14.0%	0.110 (0.025: 0.481)	0.003	-61%
<12 lymph nodes	53.6%	32.0%	0.281 (0.080: 0,984)	0.047	-40%
Conversion to open	10.7%	2.0%	*0.170 (0.017: 1.720)*	*0.13*	-81%
Total costs	€ 19.585	€ 12.827	-803 (-14326: 7327)	0.87	-35%
Primary operation time	3.39	3.05	0.66 (0.06: 1.15)	0.034	-10%
Length of hospital stay	16.35	12.46	0.63 (-8.22: 6.29)	0.86	-24%

Odds ratios and p-values were adjusted for differences in patient characteristics (listed in Table 1) in a logistic regression model. Odds ratios and p-values written in *Italic* were not adjusted for patient characteristics due to the small number of events for those outcomes.

DISCUSSION

This is the first European study describing costs of SPL surgery for colorectal cancer. Our study showed no significant differences between clinical and financial outcomes for SPL procedures when compared to conventional laparoscopic procedures. Results of SPL in the second year (2012) improved as compared to the introduction year (2011).

SPL techniques in our institution were first introduced in the more simple, benign procedures, like cholecystectomies and appendectomies as shown in an earlier (feasibility) study of our group [15,16]. After 1 year, SPL surgeons translated this technique to the more difficult procedures, like colorectal (cancer) surgery. So far, only two randomized clinical trials (RCTs) compared single-port laparoscopic surgery with standard laparoscopy. Poon et al. described less postoperative pain after SPL colectomy where Huscher et al. showed no differences in major morbidity and mortality [26,27]. Existing literature describes longer operating times, more preoperative complications, and a technically more challenging procedure when SPL is applied [11,12]. Although over the last years SPL is (internationally) becoming more popular for colorectal procedures, literature about costs of SPL remains scarce [14].
In this study a significant shorter operating time for the SPL procedures is seen when In this study, a significantly shorter operating time for the SPL procedures is seen when compared to the conventional procedures. This might be because of a bias since the SPL procedures were not randomized; however, baseline characteristics between the groups were similar (Table 1). Shorter operating time could result in lower operating costs (personnel, etc); however, in this study, we see slightly higher operating costs for SPL procedures compared to conventional laparoscopic procedures. This is mainly because of higher costs of the port used in SPL procedures since the rest of the equipment did not differ.
During the introduction period of the SPL technique (2011), operation time for colorectal cancer resections was longer, hospital stay was prolonged, and complication rate was higher as compared to the second year (2012). This resulted in overall higher hospital costs for SPL procedures looking at 2-year averages as compared to CLR procedures (Table 4), although this difference was not significantly different. A reduction in complication rate after colorectal cancer resections might result in a decrease in healthcare costs as seen in the literature [28]. The complication rate in the SPL group decreased in
2012 as compared to the introduction year, and therefore, total hospital costs became almost similar as CLR (Table 5). If the reduction in complication after SPL procedures would further decrease, SPL might become even less expensive in the future as compared to CLR.

In the first year (2011), a very low number of harvested lymph nodes was seen in the SPL group (in 35.7% of the cases, <10 lymph nodes were harvested). In the following year (2012), a significant improvement was seen in lymph node harvesting (in 14.0% of the cases, <10 lymph nodes were harvested), resulting in lower rates as compared to the CLR group. Together with a shorter operation time and lower postoperative complication rate in the second SPL year, the improvement in number of harvested lymph nodes supports the idea of a learning curve for SPL surgery.
Single-port techniques were introduced to minimize surgical trauma and thereby enhance the postoperative recovery period. However, one of the concerns might be an increased rate of port-side hernias following singleport access [29]. In 2014, Milas et al. published a systematic review of single-port laparoscopic cholecystectomies versus multiport cholecystectomies. Overall incidence of trocar site hernia was low, but slightly higher in the SPL group. They concluded SPL to be an acceptable alternative for multiport laparoscopy with modest cosmetic benefit [30]. Since the primary outcome in this study was hospital costs up to 90 days after discharge, we did not specifically analyze for (long-term) trocar site hernias. Furthermore, the port side in SPL is frequently being used as extraction side of the specimen. In these cases, the cutaneous and fascial incisions were enlarged, thereby increasing the risk for local incisional hernias. How the findings of Milas et al. translate to colorectal cancer procedures should therefore be an impetus for further studies

Limitations

First of all, costs of specialists' fees were not uniformly registered between 2011 and 2012 and were therefore excluded in the analyses. If these costs could be incorporated in our analyses, the difference in operation costs between SPL and conventional laparoscopic surgery might become smaller due to the lower operation time for SPL resections. Shorter operating time results in less salary paid per procedure. A second limitation of this study was the selection bias, due to the retrospective character of the study, as patients were not randomized between the two study groups. Although no significant differences in patient characteristics between the two groups were seen, the extensive database of the DSCA cannot rule out any additional factors not listed in the DSCA, which influenced the choice of procedure and therefore introduced selection bias. Finally, conclusions of superiority and inferiority between the two investigated years cannot be made based on this small SPL study group.

Future perspectives

Outcome registries (like the DSCA) combined with financial data might serve as an ideal framework to address effectiveness of health care. Combining clinical and financial outcomes, as seen in this study, with patient-reported outcome measures should provide even better insights. Items as quality of life, postoperative pain, or cosmetic results should therefore be addressed in future (prospective) studies.

CONCLUSION

In conclusion, this 2-year retrospective study showed no significant differences in financial outcomes between conventional and single-port laparoscopic colorectal procedures. Hospital costs of SPL decreased after the introduction year (2011) as compared to the second year (2012). Our conclusions are based on a small SPL group, and therefore, further research is needed to validate our results

REFERENCES

1. Breukink S, Pierie J, Wiggers T. Laparoscopic versus open total mesorectal excision for rectal cancer. *Cochrane Database Syst Rev.* 2006(4):CD005200.
2. Feliciotti F, Guerrieri M, Paganini AM, et al. Long-term results of laparoscopic versus open resections for rectal cancer for 124 unselected patients. *Surgical endoscopy.* 2003;17(10):1530-1535.
3. Lacy AM, Garcia-Valdecasas JC, Delgado S, et al. Laparoscopy-assisted colectomy versus open colectomy for treatment of non-metastatic colon cancer: a randomised trial. *Lancet.* 2002;359(9325):2224-2229.
4. Hotta T, Yamaue H. Laparoscopic surgery for rectal cancer: review of published literature 2000-2009. *Surgery today.* 2011;41(12):1583-1591.
5. Jefferies MT, Evans MD, Hilton J, Chandrasekaran TV, Beynon J, Khot U. Oncological outcome after laparoscopic abdominoperineal excision of the rectum. *Colorectal disease : the official journal of the Association of Coloproctology of Great Britain and Ireland.* 2012;14(8):967-971.
6. Bonjer HJ, Deijen CL, Abis GA, et al. A randomized trial of laparoscopic versus open surgery for rectal cancer. *The New England journal of medicine.* 2015;372(14):1324-1332.
7. Hardy KM, Kwong J, Pitzul KB, et al. A cost comparison of laparoscopic and open colon surgery in a publicly funded academic institution. *Surgical endoscopy.* 2014;28(4):1213-1222.
8. Delaney CP, Kiran RP, Senagore AJ, Brady K, Fazio VW. Case-matched comparison of clinical and financial outcome after laparoscopic or open colorectal surgery. *Ann Surg.* 2003;238(1):67-72.
9. Noblett SE, Horgan AF. A prospective case-matched comparison of clinical and financial outcomes of open versus laparoscopic colorectal resection. *Surgical endoscopy.* 2007;21(3):404-408.
10. Dowson HM, Huang A, Soon Y, Gage H, Lovell DP, Rockall TA. Systematic review of the costs of laparoscopic colorectal surgery. *Diseases of the colon and rectum.* 2007;50(6):908-919.
11. Antoniou SA, Koch OO, Antoniou GA, et al. Meta-analysis of randomized trials on single-incision laparoscopic versus conventional laparoscopic appendectomy. *American journal of surgery.* 2014;207(4):613-622.
12. Fung AK, Aly EH. Systematic review of single-incision laparoscopic colonic surgery. *The British journal of surgery.* 2012;99(10):1353-1364.
13. Markar SR, Wiggins T, Penna M, Paraskeva P. Single-incision versus conventional multiport laparoscopic colorectal surgery-systematic review and pooled analysis. *Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract.* 2014;18(12):2214-2227.
14. Sulu B, Gorgun E, Aytac E, Costedio MM, Kiran RP, Remzi FH. Comparison of hospital costs for single-port and conventional laparoscopic colorectal resection: a case-matched study. *Techniques in coloproctology.* 2014;18(9):835-839.
15. van der Linden YT, Boersma D, van Poll D, Lips DJ, Prins HA. Single-port laparoscopic appendectomy in children : single center experience in 50 patients. *Acta chirurgica Belgica.* 2015;115(2):118-122.

16. van der Linden YT, Bosscha K, Prins HA, Lips DJ. Single-port laparoscopic cholecystectomy vs standard laparoscopic cholecystectomy: A non-randomized, age-matched single center trial. *World J Gastrointest Surg.* 2015;7(8):145-151.
17. Van Leersum NJ, Snijders HS, Henneman D, et al. The Dutch surgical colorectal audit. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2013;39(10):1063-1070.
18. Kolfschoten NE, van Leersum NJ, Gooiker GA, et al. Successful and safe introduction of laparoscopic colorectal cancer surgery in Dutch hospitals. *Annals of surgery.* 2013;257(5):916-921.
19. Performation. http://www.performation.com.
20. Klarenbeek BR, Coupe VM, van der Peet DL, Cuesta MA. The cost effectiveness of elective laparoscopic sigmoid resection for symptomatic diverticular disease: financial outcome of the randomized control Sigma trial. *Surgical endoscopy.* 2011;25(3):776-783.
21. Kaplan RS, Anderson SR. Time-driven activity-based costing. *Harvard business review.* 2004;82(11):131-138, 150.
22. Porter ME, Lee TH. The Strategy That Will Fix Health Care. *Harvard business review.* 2013;91(12):24-24.
23. McCulloch CE, Searle, Shayle R. *Generalized, Linear, and Mixed Models.* 1st ed. New York: John Wiley & Sons; 2001.
24. Lindsey JK, Jones B. Choosing among generalized linear models applied to medical data. *Statistics in medicine.* 1998;17(1):59-68.
25. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *Journal of chronic diseases.* 1987;40(5):373-383.
26. Poon JT, Cheung CW, Fan JK, Lo OS, Law WL. Single-incision versus conventional laparoscopic colectomy for colonic neoplasm: a randomized, controlled trial. *Surgical endoscopy.* 2012;26(10):2729-2734.
27. Huscher CG, Mingoli A, Sgarzini G, et al. Standard laparoscopic versus single-incision laparoscopic colectomy for cancer: early results of a randomized prospective study. *American journal of surgery.* 2012;204(1):115-120.
28. Govaert JA, van Bommel AC, van Dijk WA, van Leersum NJ, Tollenaar RA, Wouters MW. Reducing Healthcare Costs Facilitated by Surgical Auditing: A Systematic Review. *World journal of surgery.* 2015.
29. Alptekin H, Yilmaz H, Acar F, Kafali ME, Sahin M. Incisional hernia rate may increase after single-port cholecystectomy. *Journal of laparoendoscopic & advanced surgical techniques Part A.* 2012;22(8):731-737.
30. Milas M, Devedija S, Trkulja V. Single incision versus standard multiport laparoscopic cholecystectomy: up-dated systematic review and meta-analysis of randomized trials. *The surgeon : journal of the Royal Colleges of Surgeons of Edinburgh and Ireland.* 2014;12(5):271-289.

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, hematology, clinical chemistry, microbiology
Consulting	Consults other medical specialist, outpatient department visits
Materials	Blood products, prostheses and implants
Other	Electrocardiography, spirometry, physiotherapy, medical rehabilitation

CHAPTER 7

J.A. Govaert
N. Lijftogt
W. A. van Dijk
L. Tseng
R. Liem
R.A.E.M. Tollenaar
M. Fiocco
M.W.J.M. Wouters

COLORECTAL CANCER SURGERY FOR OBESE PATIENTS: FINANCIAL AND CLINICAL OUTCOMES OF A DUTCH POPULATION-BASED REGISTRY

Journal of surgical oncology 2016

On behalf of the Dutch Value Based Healthcare Study Group:
B. Lamme, MD, PhD (Albert Schweitzer Ziekenhuis, Dordrecht); D.A. Hess MD, PhD (Antonius ziekenhuis, Sneek); H.J. Belgers, MD (Atrium-Orbis, Heerlen); O.R. Guicherit, MD, PhD (MCH-Bronovo, Den Haag); C. Rosman, MD, PhD (Canisius Wilhelmina Ziekenhuis, Nijmegen); Prof H.J.T. Rutten, MD, PhD, FRCS (Catharina Hospital, Eindhoven/ Maastricht University Medical Hospital, Maastricht); F.N.L. Versluijs-Ossewaarde. MD (Diaconessenhuis, Meppel); E.S. Van der Zaag, MD, PhD (Gelre Ziekenhuizen, Apeldoorn); L.N.L. Tseng, MD (Groene Hart Ziekenhuis, Gouda); E.J.R. de Graaf, MD, PhD (IJsselland Hospital, Capelle aan den Ijssel); W.J. Vles, MD, PhD (Ikazia Ziekenhuis, Rotterdam); E.G.J.M. Pierik, MD, PhD (Isala Kliniek, Zwolle); H.A. Prins, MD, PhD (Jeroen Bosch Ziekenhuis, Den Bosch); P.H.M. Reemst, MD (Máxima Medisch Centrum, Veldhoven); E.C.J. Consten, MD, PhD (Meander Medisch Centrum, Amersfoort); S.A. Koopal, MD (Leeuwarden Medical Centre, Leeuwarden); P.A. Neijenhuis, MD, ScS (Alrijne Ziekenhuis, Leiderdorp); G.H.H. Mannaerts, MD, PhD (Sint Franciscus Gasthuis, Rotterdam); A.B. Smits, MD (St. Antonius Ziekenhuis, Nieuwegein); D.H.C. Burger, MD (Elisabeth-Tweesteden Ziekenhuis, Tilburg); M.G.A. van IJken, MD, PhD (Van Weel-Bethesda Ziekenhuis, Dirksland); P. Poortman, MD, PhD (Waterlandziekenhuis, Purmerend); M.J.P.M. Govaert, MD (Westfriesgasthuis, Hoorn); W.A. Bleeker, MD, PhD (Wilhelmina Hospital Assen); F.C. Den Boer, MD, PhD (Zaans Medical Center); F. Wit, MD (Ziekenhuis Tjongerschans, Heerenveen); Ph. M. Kruyt, MD (Ziekenhuis Gelderse Vallei, Ede); A. Mearadji, MD, PhD (Bravis Ziekenhuis, Bergen op Zoom); J.T. Heikens, MD, PhD (Ziekenhuis Rivierenland, Tiel)

ABSTRACT

Background and Objectives

The objective of this study was to explore the association among adverse events, body mass index (BMI), and hospital costs after colorectal cancer surgery in a country with an intermediate BMI distribution.

Methods

All colorectal cancer procedures in 29 Dutch hospitals listed in a 2010–2012 population-based database and with a BMI>18.5 were included (n=8687). Hospital costs were measured uniformly and based on time-driven activity-based costing. The BMI classification of the World Health Organization was used.

Results

Patients in obesity classes 1 (23.6% [after risk-adjustment OR 1.245, CI 1.064–1.479, P.0.007]) and ≥ 2 (28.1% [after risk-adjustment OR 1.816, CI 1.382–2.388, P<0.001]) were associated with more severe complications and higher hospital costs (€14,294, +9.6%, after risk-adjustment +7.9%, P<0.001; and €15,913 +22.0%, after risk-adjustment +21.2%, P<0.001, respectively) than normal weight patients (20.8% and €13,040, respectively). Pre-obese patients had significantly lower mortality rates (2.7%, after risk-adjustment, OR 0.756, CI 0.577–0.991, P.0.042) than normal-weight patients (3.9%).

Conclusions

Obese surgical colorectal cancer patients in a country with an intermediate BMI distribution are associated with a significant increase in hospital costs because these patients suffer from more severe complications. This is the first study to provide evidence for the "obesity paradox" for mortality in colorectal cancer surgery

INTRODUCTION

According to the World Health Organization more than 1.9 billion adults are overweight (body mass index (BMI) >25 kg/m^2) and of these over 600 million are obese (BMI >30 kg/m^2) [1]. Obesity is a major risk factor for several diseases, such as cardiovascular diseases, diabetes and several types of cancers [2].

One of the most well-known obesity-linked cancers is colorectal cancer [2,3], the second leading cause of cancer-related deaths in the United States [4] and Europe [5]. Colorectal surgery is related to a disproportional share of adverse events [6] and its complications account for a dramatic increase in hospital costs [7]. A specific population that is at risk includes colorectal cancer patients suffering from obesity. These patients are associated with increased postoperative risks of pulmonary complications, wound infections, and cardiovascular events [8-10]. Regarding mortality, evidence from general surgery suggest that there seems to be a so-called “obesity paradox” that involves pre-obese and mildly obese surgical patients having lower mortality rates than patients of normal weight [11]. However, for colorectal cancer patients, this relationship has not yet been identified [8,9].

Multi-center studies describing whether obesity has a major impact on hospital costs after colorectal cancer surgery are scarce. Existing studies describing this relationship have been conducted in the relatively obese populations of the United States [10] and New Zealand [9] and the relative none-obese population in Japan [8]. It remains unclear, however, whether these results can be generalized to countries with more intermediate BMI distributions such as Sweden, France and the Netherlands [12,13]. Therefore, the aim of this study was to explore the association between hospital costs and BMI after colorectal cancer surgery in a population-based registry from a country with an intermediate BMI distribution. Because hospital costs are closely related to complications [7], a secondary aim was to explore the association between adverse events (morbidity and mortality) after colorectal cancer surgery and BMI.

METHODS

Clinical data

The data set was retrieved from the Dutch Surgical Colorectal Audit (DSCA), a nationwide, population-based database in which detailed patient, tumor, diagnostic, procedural, and outcome data are registered for all patients who undergo resection of primary colorectal carcinoma in the Netherlands. The DSCA shows almost 100% completeness on most items and a high accuracy level in terms of validation (97% in 2012) against the Netherlands Cancer Registry dataset [14,15]. A detailed description of the DSCA has been published recently [15,16].

Financial data

The economic evaluation was conducted from the hospital perspective. Therefore, only "in-hospital" costs were considered. The costs were accounted for from the day of the initial surgery until discharge (= primary admission) and within the first 90 days after discharge (= Q1). For each hospital, the 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 [17]. Costs were calculated using Time-Driven Activity-Based Costing (TD-ABC) methodology [18] which is an advanced method for understanding (hospital) costs [19]. Briefly, the TD-ABC 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 [20]. The cost price calculations were standardized by Performation; therefore, uniformity in the methodology existed among 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 and the different models themselves. Different activities were grouped into eight categories, as shown in Supplemental

Table 1. All activities contained direct hospital costs (e.g., personnel, material, and equipment) and indirect hospital costs. For example, direct costs for an inpatient day (category "ward") consisted of the (a) salaries of the ward nurses; (b) material costs, including bed linens and bandages; and (c) depreciation of equipment, such as beds and ward inventory. Examples of indirect costs included costs related to information technology, building depreciation, cleaning, and catering. Specialists' fees, medication costs, and costs for dialyses were excluded because the registration of these parameters was not uniform across the participating hospitals, which made an equal comparison impossible.

A detailed description of the database of the Dutch Value Based Healthcare study has recently been published [7,21].

Inclusion criteria

Hospital selection (n=29) was based on the availability of detailed cost-price information from Performation for three consecutive years (2010, 2011, and 2012). Twenty-one hospitals (72%) had surgical teaching programs. The 29 participating hospitals had a representative BMI distribution of colorectal cancer patients that was compared with hat of the nationwide BMI distribution of colorectal cancer patients (Supplemental Table 2). Patients who underwent surgical resection for primary colorectal cancer between January 1st, 2010 and December 31st, 2012 had to be registered in the DSCA before December 1st 2013. Unique Patient Identification Numbers (combined with the hospital of admission) were used to match patients registered in the DSCA to the financial database. The minimum data requirements to consider a patient eligible for matching with the financial dataset included information about tumor location, date of surgery, mortality status, and BMI.

Definitions

Weight categories were selected according to the WHO standards: normal weight [BMI 18,5-24,99 kg/m^2], pre-obese [BMI 25-29,99 kg/m^2], obesity class 1 [BMI 30-34,99 kg/m^2] and obesity class ≥2 (containing both obesity class 2 [BMI 35-39,99 kg/m^2] and obesity class 3 [BMI > 40 kg/m^2])[1].

Primary outcome measures for quality of healthcare were (1) postoperative mortality, defined as in-hospital or 30-day mortality; (2) severe complication, defined as in-hospital or 30-day adverse outcomes leading to mortality, reintervention (percutaneous or operative), or a post-operative primary hospital stays of at least 14 days [[7,22] and 3) and (3) failure to rescue (FTR), defined as the percentage of patients with severe complications who died in-hospital or within 30 days after resection [22]. Secondary clinical outcome measures that occurred in-hospital or within 30 days after resection were (4) any complications; (5) mild complications, defined as complications that were not severe; (6) reintervention (surgical, radiological or endoscopic); (7) anastomotic leakage/abscess; (8) R1/R2 resection; (9) resections for which fewer than 10 lymph nodes were retrieved; (10) duration of the primary operation; and (11) length of hospital stay (primary admission only, and the day of surgery was day 1).

Financial outcome measures were (1) total costs (= all hospital costs from primary admission to 90 days after discharge, which, therefore, included the costs of re-admission and -operation) and (2) costs per category, as listed in Supplemental Table 1.

Analysis

Chi-square test and One-way Anova were used to investigate differences between patients' characteristics in the three different groups (Table 1).

Absolute clinical and financial outcomes were presented unadjusted (and adjusted were stated). To investigate differences between the BMI groups for all outcomes of interest, a multivariate mixed effects model with risk adjustment for patients' characteristics and hospitals as random effects was estimated. Mixed models include additional random-effect terms and are appropriate to handle nested data (like patients in each hospital) and unequal study [23,24]. Patients' characteristics included in the analyses were sex, age (categorical), presence of synchronous tumors, location of tumor, stage of tumor (TNM), pre-operative radiotherapy, distant metastases, metastasectomy, and extended resections. American Society of Anesthesiologists (ASA) classification and Charlson score were not used for risk-adjustment as these characteristics have a strong correlation with BMI status.

As several continuous outcomes showed skewed distributions a logarithmic transformation of the original variable has been applied. Logarithmic transformations of variables in a regression model are a common way to handle a highly skewed variable into one that is more a proximately normal. Results are then reported in the original scale by taking the exponential transformation of the estimated regression coefficients. For all adjusted outcomes representing costs, the difference between each BMI group and the reference group (normal weight) was reported as an adjusted percentage.

Statistical analyses were performed by using SPSS (version 20; IBM) and R (version 18). Outcomes are presented as the mean. Confidence intervals (CI) were stated at 95%.

RESULTS

A total of 9,913 patients were listed in the database. Patients who were underweight (n=162; 1.6%) and patients with unknown BMIs (n=1,064; 10.7%) were excluded, which resulted in 8,687 patients who were eligible for the analysis. Of the included patients, 3,666 (42.2%) were normal weight, 3,577 (41.2%) were pre-obese, 1,145 (13.2%) were obese class 1, and 299 (3.4%) were obese class ≥2. All analyzed patients, tumors and procedural characteristics of the studied population are shown in Table 1.

Clinical outcomes

Mortality rates were lower for the pre-obese patients (2.7%) and the obesity class 1 patients (2.4%) and higher for the obesity class ≥2 patients (4.7%) than for the normal-weight patients (3.9%). After adjustment for patient characteristics and treatment hospitals, the mortality rates were significantly lower for the pre-obese patients (OR 0.756, CI 0.577–0.991, P=0.042) and significant higher for the obesity class ≥2 patients (OR 1.887, CI 1.052–3.385, P=0.032) than for the normal-weight patients (Table 2).

Table 1. Patient, tumor and treatment characteristic of patients enrolled in this study stratified by BMI category

		Total	**Normal weight**	**Pre-obese**	**Obese class I**	**Obese class ≥2**	
		N (%)	N (%)	N (%)	N (%)	N (%)	*p*-value
Total		8687 (100%)	3666 (42.2%)	3577 (41.2%)	1145 (13.2%)	299 (3.4%)	-
Characteristics for risk-adjustment							
Sex	Male	4873 (56.1%)	1874 (51.1%)	2226 (62.2%)	646 (56.4%)	127 (42.5%)	<0.001
Age (mean)		69.6 y	69.1 y	70.0 y	68.4 y	67.85 y	<0.001
Synchronous tumors	Yes	292 (3.4%)	120 (3.3%)	119 (3.3%)	43 (3.8%)	10 (3.3%)	0.89
Tumor location	Right colon	2766 (31.8%)	128 (33.5%)	1068 (29.9%)	366 (32%)	104 (34.8%)	0.001
	Left colon	972 (11.2%)	422 (11.5%)	411 (11.5%)	109 (9.5%)	30 (10%)	
	Sigmoid	2320 (26.7%)	916 (25%)	1030 (28.8%)	288 (25.2%)	86 (28.8%)	
	Rectum	2629 (30.3%)	1100 (30.0%)	1068 (29.9%)	382 (33.4%)	79 (26.4%)	
Tumor stage (TNM)	Stage unknown	165 (1.9%)	79 (2.2%)	64 (1.8%)	17 (1.5%)	5 (1.7%)	0.001
	Stage 0	161 (1.9%)	64 (1.8%)	67 (1.9%)	25 (2.2%)	5 (1.7%)	
	Stage 1	581 (6.7%)	215 (5.9%)	241 (6.8%)	102 (9.0%)	23 (7.7%)	
	Stage 2	1842 (21.2%)	734 (20.1%)	801 (22.6%)	249 (22.0%)	58 (19.5%)	
	Stage 3	4800 (55.3%)	2036 (55.9%)	1974 (55.6%)	623 (55.0%)	167 (56.2%)	
	Stage 4	1075 (12.4%)	515 (14.1%)	405 (11.4%)	116 (10.2%)	39 (13.1%)	
Preoperative radiotherapy	None	6431 (74%)	2717 (74.1%)	2655 (74.2%)	825 (72.1%)	234 (78.3%)	0.007
	5 x 5 Gy	1250 (14.4%)	492 (13,4%)	550 (15,4%)	176 (15.4%)	32 (10.7%)	
	50-60 Gy / else	1006 (11.6%)	457 (12.5%)	372 (10.4%)	144 (12.6%)	33 (11.0%)	
Distant metastases	Yes	888 (10.2%)	414 (11.3%)	329 (9.2%)	112 (9.8%)	33 (11.0%)	0.028
Metastasectomy	Yes	262 (3.0%)	122 (3.3%)	96 (2.7%)	35 (3.1%)	9 (3.0%)	0.46
Extended resections	Yes	723 (8.3%)	345 (9,4%)	267 (7.5%)	81 (7.1%)	30 (10%)	0.006
Urgency of resection	Urgent	970 (11.2%)	480 (13.1%)	357 (10.0%)	104 (9,1%)	29 (9.7%)	<0.001

Table 1. Patient, tumor and treatment characteristic of patients enrolled in this study stratified by BMI category (continued)

		Total	**Normal weight**	**Pre-obese**	**Obese class I**	**Obese class ≥2**	
		N (%)	N (%)	N (%)	N (%)	N (%)	*p*-value
Other characteristics (not used for risk-adjustment)							
Charlson score	Charlson 0	4662 (53.7%)	2116 (57.7%)	1907 (53.3%)	526 (45.9%)	113 (37.8%)	<0.001
	Charlson 1	1989 (22.9)	780 (21.3%)	807 (22.6%)	323 (28.2%)	79 (26.4%)	
	Charlson 2+	2036 (23.4%)	770 (21.0%)	863 (24.1%)	296 (25.9%)	107 (35.8%)	
ASA score	I-II	6598 (76.0%)	2879 (78.6%)	2751 (77.0%)	809 (70.7%)	159 53.2%)	<0.001
	III	1952 (22.5%)	730 (19.9%)	774 (21.7%)	315 (27.5%)	133 (44.5%)	
	IV-V	126 (1.5%)	52 (1.4%)	47 (1.3%)	20 (1.7%)	7 (2.3%)	
Surgical approach	Laparoscopic	4143 (47.7%)	1742 (47.7%)	1770 (49.7%)	505 (44.3%)	126 (42.1%)	0.002
Anastomosis or stoma	Anastomosis	5545 (63.8%)	2386 (67.4%)	2264 (65.6%)	703 (64.2%)	192 (67.4%)	0.25
	Anastomose & stoma	1119 (12.9%)	457 (12.9%)	484 (14.0%)	146 (13.3%)	32 (11.2%)	
	Stoma	1704 (19.6%)	695 (19.6%)	702 (20.3%)	246 (22.5%)	61 (21.4%)	

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

Severe complication rates were higher for the pre-obese patients (22.4%), the obesity class 1 patients (23.6%) and the obesity class ≥2 patients (28.1%) than for the normal-weight patients (20.8%). After adjustment for patient characteristics and treatment hospitals, the severe complication rates were significantly higher for the obese class 1 patients (OR 1.245, CI 1.064–1.479, P=0.007) and the obesity class ≥2 patients (OR 1.816, CI 1.382–2.388, P<0.001) than for the normal weight patients (Table 2).

After adjustment for patient characteristics and treatment hospitals, outcomes such as reintervention rates, anastomotic leakage rates, radical resections and <10 lymph nodes did not significantly differ between the pre-obese/obese patients and the normal-weight patients (Table 2).

Table 2. Clinical outcomes stratified by BMI category

	Normal weight	**Pre-obese**		**Obesity class 1**		**Obesity class ≥2**	
Outcomes	(reference)		OR (95% CI)*		OR (95% CI)*		OR (95% CI)*
Mortality	3.9%	**2.7%**	0.756 (0.577:0.991)	2.4%	0.805 (0.528: 1.226)	**4.7%**	1.887 (1.052:3.385)
Complications	31.8%	**34.2%**	1.113 (1.003: 1.234)	**36.8%**	1.328 (1.147: 1.538)	**43.1%**	1.953 (1.519: 2.510)
Mild complication	11.0%	11.7%	1.069 (0.921: 1.241)	**13.2%**	1.245 (1.015: 1.529)	**15.1%**	1.480 (1.052: 2.081)
Severe complications	20.8%	22.4%	1.101 (0.980: 1.238)	**23.6%**	1.254 (1.064: 1.479)	**28.1%**	1.816 (1.382: 2.388)
Reintervention	12.9%	15.0%	1.142 (0.996: 1.309)	14.8%	1.165 (0.959: 1.415)	14.7%	1.247 (0.888: 1.751)
Anastomic leakage	7.6%	7.0%	0.994 (0.834: 1.185)	8.1%	1.011 (0.787: 1.299)	6.7%	0.879 (0.548: 1.411)
R1/R2 resection	3.9%	3.0%	0.802 (0.617: 1.042)	3.1%	0.831 (0.567: 1.217)	3.5%	0.903 (0.469: 1.737)
< 10 lymph nodes	29.8%	29.5%	0.955 (0.856: 1.065)	30.7%	1.005 (0.859: 1.174)	27.4%	0.956 (0.722: 1.266)

Unadjusted percentages are shown. Outcomes in bold were significant different (p<0.05). * Odds ratios and 95% confidence intervals (CI) were adjusted for patient characteristics and hospital of treatment.

Operation time was longer for the pre-obese patients (2.94 hr), obesity class 1 patients (3.03 hr), and obesity class ≥2 patients (3.27 hr) than for the normal-weight patients (2.83 hr). After adjustment for patient characteristics and treatment hospitals, the operation times were significantly longer for all of the overweight categories than for the normal-weight patients. The lengths of hospital stay (means) were longer for the pre-obese patients (9.93 days), obesity class 1 patients (10.41 days), and obesity class ≥2 patients (10.85 days) than for the normal-weight patients (9.55 days). After adjustment for patient characteristics and treatment hospitals, the lengths of hospital stay were significantly longer for all of the overweight categories than for the normal-weight patients (Table 3).
FTR rates were lower for the pre-obese patients (12.1%), obesity class 1 patients (10.4%), and obesity class ≥2 patients (16.7%) than for the normal-weight patients (18.6%). After adjustment for patient characteristics and treatment hospitals, the FTR rates were significant lower for the pre-obese patients (OR 0.594, CI 0.434–0.811, P=0.001) and obesity class 1 patients (OR 0.477, CI 0.292–0.781, P=0.003) than for the normal-weight patients (Figure 3A).

Table 3. Clinical outcomes stratified by BMI category

	Normal weight	**Pre-obese**		**Obesity class 1**		**Obesity class ≥2**	
Outcomes	(reference)		% incr. (95% CI)*		% incr. (95% CI)*		% incr. (95% CI)*
Operation time (hours)	2.83	**2.94**	+3.8% (2.385: 5.313)	**3.03**	+6.9% (4.798: 9.132)	**3.27**	+15.5% (11.437: 19.684)
LOS (days)	9.55	**9.93**	+4.0% (1.191: 6.955)	**10.41**	+9.0% (4.739: 13.416)	**10.85**	+13.7% (5.962: 21.963)

Unadjusted outcomes are shown. Outcomes in bold were significant different (p<0.05). Operation time for primary operation is shown. Length of hospital stay (LOS) for primary admission is shown (day of surgery = day 1). * Percentage increase (% incr.) and 95% confidence intervals (CI) were adjusted for patient characteristics and hospital of treatment.

Financial outcomes

Total hospital costs were higher for the pre-obese (€13,818, +6.0%), obesity class 1 (€14,294, +9.6%), and obesity class ≥2 (€15,913, +22.0%) patients than for the normal-weight patients (€13,040). After adjustment for patient characteristics and treatment hospitals, the total hospital costs were significantly greater for the obesity class 1 patients (+7.9%, CI 3.6–12.3%, P<0.001) and obesity class ≥2 patients (+21.2%, CI 12.9–30.0%, P<0.001) than for the normal-weight patients (Figure 1). In detail, the costs related to the wards, operations, and intensive care units were the greatest contributors to total hospital costs (Figures 2A–C). After adjustment for patient characteristics and treatment hospitals, the pre-obese patients had significantly higher operation costs (Figure 2B) than the normal-weight patients. After adjustment for patient characteristics and treatment hospitals, the obesity class 1 patients had significantly higher hospital costs related to the wards (Figure 2A), operation (Figure 2B), laboratory (Figure 2D), and consultation (Figure 2E). After

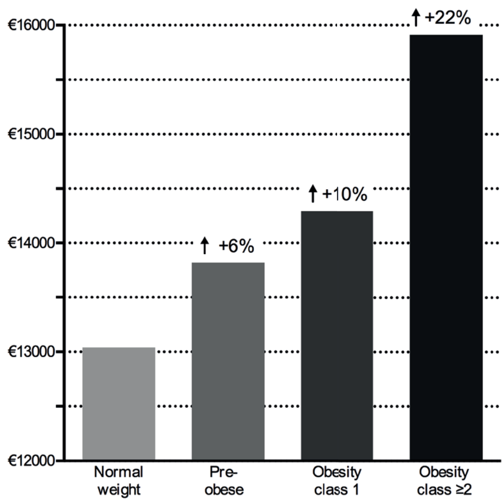


Figure 1. Average costs after colorectal cancer surgery stratified by BMI category

	Unadjusted		After adjustment*		
BMI groups	Euro	Increase	Increase	95% CI	p-value
Normal weight	€ 13040	-	-	-	-
Pre-obese	€ 13818	6.0%	2.4%	(-0.4%: 5.3%)	0.094
Obesity class 1	€ 14294	9.6%	7.9%	(3.6%: 12.3%)	<0.001
Obesity class ≥ 2	€ 15913	22.0%	21.2%	(12.9%: 30.0%)	<0.001

Costs are calculated from primary surgery up to 90 days after discharge.
* Adjusted for patient characteristics and hospital of treatment.

adjustment for patient characteristics and treatment hospital, the obesity class ≥2 patients had significantly greater hospital costs related to the wards (Figure 2A), operation (Figure 2B), laboratory (Figure 2D), consultation (Figure 2E), and other costs (Figure 2H).

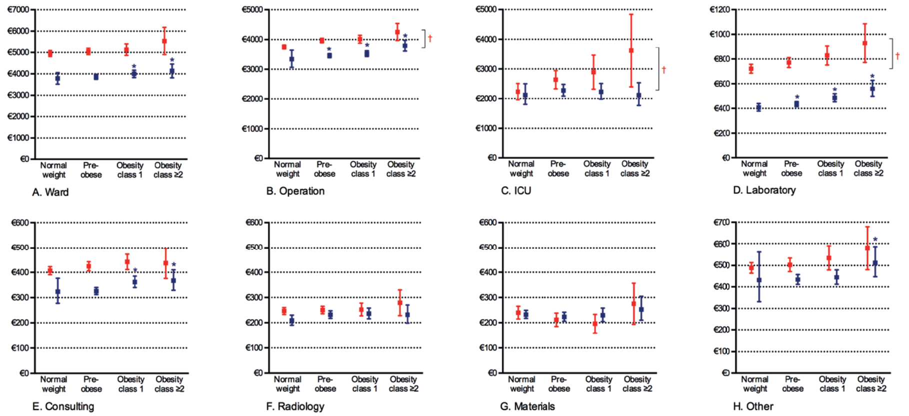


Figure 2. Comparison of all cost categories between the different BMI groups
Costs are calculated from primary surgery up to 90 days after discharge (therefore cost of re-operations and re-admissions are included).
Blue: Adjusted outcomes for patient characteristics and hospital of treatment. * p<0.05 as compared to normal weight.
Red: Unadjusted outcomes. † p<0.05 between the different BMI groups using ANOVA.

Costs for patients without complications were lower for the pre-obese patients (€9,028, -3.1%) and higher for the obesity class 1 (€9,768, +4.9%) and obesity class ≥2 (€10,195, +9.5%) patients than for the normal-weight patients (€9,313). After adjustment for patient characteristics and treatment hospitals, the costs of the obesity class 1 (+5.6%, CI 2.1–9.2%, P=0.001) and obesity class ≥2 patients (+14.2%, CI 7.2–21.8%, P<0.001) were significantly greater than those of the normal-weight patients (Figure 3B). The costs of the patients with severe complications were higher for the pre-obese (€28,827, +12.0%), obesity class 1 (€27,995 +8.8%,), and obesity class ≥2 (€29,915, +16.3%) patients than for the normal-weight patients (€25,727). After adjustment for patient characteristics and treatment hospital, the costs of the pre-obese patients (+8.7%, CI 1.9–16.1%, P=0.012) were significantly greater than those of the normal-weight patients (Figure 3C).

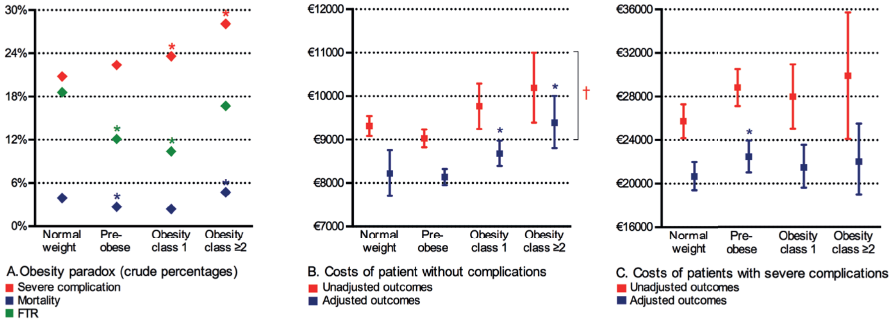


Figure 3. Adverse outcomes (obesity paradox) (A) and costs of patients without complications (B) and with severe complications (C)

A. Obesity paradox (crude percentages)

B. Costs of patient without complications

C. Costs of patients with severe complications

* Outcomes are significant different as compared to normal weight after adjustment for patient characteristics and hospital of treatment ($p<0.05$). † Significant differences for unadjusted outcomes between the BMI groups using ANOVA ($p<0.05$). Abbreviations: BMI, Body Mass Index; FTR, failure to rescue.

DISCUSSION

This population-based report shows that surgical colorectal cancer patients with obesity are associated with a significant increase in hospital costs. This increase in costs may be explained by more intensive use of resources because obese patients suffer from significantly more severe complications than normal-weight patients. Moreover, the present study is the first multi-center study to provide evidence for the “obesity-paradox” that has been seen in general surgery; that is, pre-obese patients undergoing colorectal cancer surgery have a significantly reduced risk of mortality compared with normal weight patients.

Hospital costs of obese patients undergoing colorectal cancer surgery

Both overweight and obesity place a financial burden on health services and the wider economy [25]. However, (multi-center) evidence regarding whether obesity has a major impact on hospital costs after colorectal cancer surgery remains scarce. A recent single-center study from New Zealand showed a significant increase in hospital costs for obese patients (>30 kg/m^2); however, likely due to a small sample size (n=345), no distinctions between obesity classes were noted [9]. Two recent multi-center studies reported diverse results; a study from the USA reported no differences in hospital costs between non-obese and obese patients, whereas a Japanese study reported a significant increase in hospital costs for obese patients (>30 kg/m^2) [8,10]. However, cost analyses of both multi-center studies were hampered by their reliance on administrative claim data [8,10] and, therefore, did not analyze real costs [19].

In this population-based study, after adjustment for patient characteristics and treatment hospitals, higher hospital costs were observed for both obesity class 1 and obesity class ≥2 patients than for normal-weight patients (Figure 1). These differences were most likely due to the increase in the severe complication rate with each increase in BMI because severe complications after colorectal cancer surgery account for a substantial rise in hospital costs [7]. This supposition is also supported by the increased (crude) costs related to wards (Figure 2A), (re-) operations (Figure 2B), and intensive care units (Figure 2C) for obese patients. The lack of accurate and comparable cost calculations across different institutions is a known limitation of multi-center studies analyzing hospital costs. Therefore, a major strength of this study was the use of uniform cost calculations for every individual patient based on the TD-ABC methodology [18], which is a superior method for measuring and understanding actual costs [19]. Because the TD-ABC methodology was standardized in all participating hospitals, we were able to make accurate and comparable cost calculations for all patients from the individual institutions..

The 'obesity paradox' and FTR in colorectal cancer surgery

A large NSQIP study analyzing more than 100,000 general surgery procedures (bariatric and vascular surgeries excluded) found that overweight and moderately

obese patients have lower crude and adjusted risks of mortality than normal-weight patients [11]. In the literature this phenomenon is called the ‘obesity paradox’, that is, mild obesity is associated with improved outcomes.
In the case of colorectal cancer surgery, the recent literature shows contradictory results. In a Japanese setting, gastrointestinal cancer patients with normal BMIs (23 kg/m^2) had the lowest mortality rate, although this rate was not significantly different from that of patients with obesity [8]. Regarding rectal cancer surgery, an Australian study showed no differences in clinical outcomes (complications and/or mortality) of patients with between BMIs <30 kg/m^2 and >30 kg/m^2 [26] whereas a NSQIP study from the United States of America (USA) showed a higher risk of overall morbidity for patients with BMIs >35 kg/m^2 [27]. A study from the USA study that analyzed colon cancer procedures found no significant differences in clinical outcomes (complications and/or mortality) between none-obese and obese patients [28] whereas other studies from New Zealand and the USA have found only increased risks of wound-related complications for obese patients (no significant differences in severe complications or mortality were found) [9,10,29].
In contrast to the earlier findings regarding colorectal cancer procedures[8,9,26-29], the present study provided evidence for a protective effect of pre-obesity on mortality (Table 2 and Figure 3A), similar to that found in studies that have analyzed general surgery procedures [11]. The discrepancy between those earlier studies [8,9,26-29] and the present study may be explained by the use of a detailed population-based database in the present study [14] which included patients who are not eligible for clinical trials [30]. Moreover, single-center studies [9,26,28,29] often describe the work of dedicated teams in specialized centers and, therefore, may raise questions regarding whether those results can be extrapolated to the national level. Finally, the three multi-center studies were all conducted with patients living in countries with different BMI distributions (either very low or very high BMIs) than that of the Dutch setting [8,10,27]. This may affect clinical outcomes because the percentages of body fat [31] and biological factors may differ between populations. Moreover, one may suggest that less-obese countries have less-experienced doctors and nursing staff in terms of the treatment of obese patients, which could explain the relatively higher peri- and post-operative mortality rates for those patients [8].

The pre-obese patients in this study exhibited no significant differences in severe complication rates compared with the normal weight patients; however, the rate of failure to rescue these patients was significant lower, resulting in significantly less mortality (Figure 3A). Even the obesity class 1 patients had significantly lower FTR rates, although their crude severe complication rate was significant higher (Figure 3A). No protective effect of severe obesity (class ≥2) was observed; instead, these patients had significantly higher severe complication rates and significant higher mortality rates than the normal-weight patients. The reason for this difference is difficult to identify based on our data. Remarkably, the pre-obese patients suffering from severe complications were significantly more expensive than the normal-weight patients with severe complications (Figure 3B), which may indicate more intensive (and, therefore, more expensive) treatments. However, the costs of obese patients with severe complications were not significantly higher (Figure 3B) A more likely explanation may be the interaction between metabolic regulation and the immune response [32]. The obese state is characterized by a low-grade systemic inflammation in which a number of adipokines, such as tumor necrosis factor α and some pro-inflammatory interleukins, are up-regulated [33,34]. This inflammation engages almost the same set of molecules and signaling pathways that are engaged in tissue repair [32] and, therefore, may provide a more protective state for surgery. This benefit likely has a certain cut-off point at which the disadvantages outweigh the benefits, resulting in more complications in severely obese patients (Figure 3A).

Limitations

First, a known limitation of retrospective studies is the occurrence of coding or documentation errors in large databases. This resulted in the exclusion of 10.7% of the total number of patients because the length and/or weight data were missing; therefore, no BMI could be calculated. Second, costs of specialists' fees, medication and dialyses were excluded from our analyses, which may have resulted in the underestimation of the total costs of all groups. However, we do not believe that this limitation had a major impact on our conclusions. The costs of the patients with higher BMIs may in fact be even higher because patients with higher BMIs are more likely to have more comorbidities (and, therefore, higher medication expenses), and these patients are associated with longer operation times (and, therefore, higher specialist fees). Finally, we used a population-based registry (92 hospitals) but included only 29 hospitals in our analyses because of the lack of uniform cost calculations in the other institutions. However, these 29 hospitals represent more than one-third of all colorectal cancer procedures performed in the Netherlands. Moreover, the BMI distributions of the 29 studied hospitals were almost identical to the nation-wide BMI distribution and were therefore indicative of a representative selection of the population database (Supplemental Table 2).

CONCLUSIONS

As shown in this study, healthcare providers in countries with intermediate BMI distributions should be aware of increased (i.e., more severe) complication rates and increased hospital costs when treating obese colorectal cancer patients. The present study revealed that pre-obese colorectal cancer patients were in a protective state in terms of mortality.

REFERENCES

1. World Health Organisation. 2015; http://apps.who.int/bmi/index.jsp?introPage=intro_3.html.
2. Renehan AG, Tyson M, Egger M, Heller RF, Zwahlen M. Body-mass index and incidence of cancer: a systematic review and meta-analysis of prospective observational studies. *Lancet.* 2008;371(9612):569-578.
3. Bardou M, Barkun AN, Martel M. Obesity and colorectal cancer. *Gut.* 2013;62(6):933-947.
4. Siegel R, Naishadham D, Jemal A. Cancer statistics, 2012. *CA: a cancer journal for clinicians.* 2012;62(1):10-29.
5. Ferlay J, Steliarova-Foucher E, Lortet-Tieulent J, et al. Cancer incidence and mortality patterns in Europe: estimates for 40 countries in 2012. *Eur J Cancer.* 2013;49(6):1374-1403.
6. Schilling PL, Dimick JB, Birkmeyer JD. Prioritizing quality improvement in general surgery. *Journal of the American College of Surgeons.* 2008;207(5):698-704.
7. Govaert JA, Fiocco M, van Dijk WA, et al. Costs of complications after colorectal cancer surgery in the Netherlands: Building the business case for hospitals. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2015.
8. Yasunaga H, Horiguchi H, Matsuda S, Fushimi K, Hashimoto H, Ayanian JZ. Body mass index and outcomes following gastrointestinal cancer surgery in Japan. *The British journal of surgery.* 2013;100(10):1335-1343.
9. Tapper R, Dixon L, Frampton C, Frizelle F. Impact of obesity on the cost of major colorectal surgery. *The British journal of surgery.* 2013;100(2):293-298.
10. Wick EC, Hirose K, Shore AD, et al. Surgical site infections and cost in obese patients undergoing colorectal surgery. *Archives of surgery.* 2011;146(9):1068-1072.
11. Mullen JT, Moorman DW, Davenport DL. The obesity paradox: body mass index and outcomes in patients undergoing nonbariatric general surgery. *Annals of surgery.* 2009;250(1):166-172.
12. Centraal Buro voor de Statistiek - Length and weight of persons, onderweight and overweight. 2015; http://www.cbs.nl.
13. Organisation for Economic Co-operation and Development (OECD). 2015; http://www.oecd.org.
14. Dutch Surgical Colorectal Audit.
15. Van Leersum NJ, Snijders HS, Henneman D, et al. The Dutch surgical colorectal audit. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2013;39(10):1063-1070.
16. Kolfschoten NE, van Leersum NJ, Gooiker GA, et al. Successful and safe introduction of laparoscopic colorectal cancer surgery in Dutch hospitals. *Annals of surgery.* 2013;257(5):916-921.
17. Performation. http://www.performation.com.
18. Kaplan RS, Anderson SR. Time-driven activity-based costing. *Harvard business review.* 2004;82(11):131-138, 150.
19. Porter ME, Lee TH. The Strategy That Will Fix Health Care. *Harvard business review.* 2013;91(12):24-24.

20. Mercier G, Naro G. Costing hospital surgery services: the method matters. *PloS one.* 2014;9(5):e97290.

21. Govaert JA, van Dijk WA, Fiocco M, et al. Nationwide Outcomes Measurement in Colorectal Cancer Surgery: Improving Quality and Reducing Costs. *Journal of the American College of Surgeons.* 2016;222(1):19-29 e12.

22. Henneman D, van Leersum NJ, Ten Berge M, et al. Failure-to-rescue after colorectal cancer surgery and the association with three structural hospital factors. *Ann Surg Oncol.* 2013;20(11):3370-3376.

23. McCulloch CE, Searle, Shayle R. *Generalized, Linear, and Mixed Models.* 1st ed. New York: John Wiley & Sons; 2001.

24. Lindsey JK, Jones B. Choosing among generalized linear models applied to medical data. *Statistics in medicine.* 1998;17(1):59-68.

25. Dee A, Kearns K, O'Neill C, et al. The direct and indirect costs of both overweight and obesity: a systematic review. *BMC research notes.* 2014;7:242.

26. Bokey L, Chapuis PH, Dent OF. Impact of obesity on complications after resection for rectal cancer. *Colorectal disease : the official journal of the Association of Coloproctology of Great Britain and Ireland.* 2014;16(11):896-906.

27. Smith RK, Broach RB, Hedrick TL, Mahmoud NN, Paulson EC. Impact of BMI on postoperative outcomes in patients undergoing proctectomy for rectal cancer: a national surgical quality improvement program analysis. *Diseases of the colon and rectum.* 2014;57(6):687-693.

28. Bamboat ZM, Kinnier C, Dursun A, et al. Short-term outcomes in obese patients after colectomy for adenocarcinoma at a bariatric center. *Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract.* 2012;16(10):1923-1928.

29. Amri R, Bordeianou LG, Sylla P, Berger DL. Obesity, outcomes and quality of care: body mass index increases the risk of wound-related complications in colon cancer surgery. *American journal of surgery.* 2014;207(1):17-23.

30. Dreyer NA, Garner S. Registries for robust evidence. *Jama.* 2009;302(7):790-791.

31. Gallagher D, Heymsfield SB, Heo M, Jebb SA, Murgatroyd PR, Sakamoto Y. Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. *The American journal of clinical nutrition.* 2000;72(3):694-701.

32. Hotamisligil GS. Inflammation and metabolic disorders. *Nature.* 2006;444(7121):860-867.

33. Gil A, Maria Aguilera C, Gil-Campos M, Canete R. Altered signalling and gene expression associated with the immune system and the inflammatory response in obesity. *The British journal of nutrition.* 2007;98 Suppl 1:S121-126.

34. Odrowaz-Sypniewska G. Markers of pro-inflammatory and pro-thrombotic state in the diagnosis of metabolic syndrome. *Advances in medical sciences.* 2007;52:246-250.

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

Supplemental Table 2. Distribution of Body Mass Index (BMI) in the participating hospitals and in all Dutch hospitals (2010-2012)

	This study (n=29)	**All Dutch hospitals (n=92)***
Number patients	8687	20384
BMI class		
Normal weight	3666 (42.2%)	8473 (41.6%)
Pre-obese	3577 (41.2%)	8461 (41.5%)
Obesity class I	1145 (13.2%)	2715 (13.3%)
Obesity class ≥II	299 (3.4%)	735 (3.6%)

* Retrieved from the Dutch Surgical Colorectal Audit. Only patients with information on tumor location, length and weight, date of surgery, mortality status and with a BMI >18.5 are shown.

CHAPTER 8

J.A. Govaert
M.J.P.M. Govaert
M. Fiocco
W.A. van Dijk
R.A.E.M. Tollenaar
M.W.J.M. Wouters

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

Journal of Surgical Oncology 2016

On behalf of the Dutch Value Based Healthcare Study Group

B. Lamme, MD, PhD (Albert Schweitzer Ziekenhuis, Dordrecht); D.A. Hess MD, PhD (Antonius ziekenhuis, Sneek); H.J. Belgers, MD (Atrium-Orbis, Heerlen); O.R. Guicherit, MD, PhD (MCH-Bronovo, Den Haag); C. Rosman, MD, PhD (Canisius Wilhelmina Ziekenhuis, Nijmegen); Prof H.J.T. Rutten, MD, PhD, FRCS (Catharina Hospital, Eindhoven/ Maastricht University Medical Hospital, Maastricht); F.N.L. Versluijs-Ossewaarde. MD (Diaconessenhuis, Meppel); E.S. Van der Zaag, MD, PhD (Gelre Ziekenhuizen, Apeldoorn); L.N.L. Tseng, MD (Groene Hart Ziekenhuis, Gouda); E.J.R. de Graaf, MD, PhD (IJsselland Hospital, Capelle aan den Ijssel); W.J. Vles, MD, PhD (Ikazia Ziekenhuis, Rotterdam); E.G.J.M. Pierik, MD, PhD (Isala Kliniek, Zwolle); H.A. Prins, MD, PhD (Jeroen Bosch Ziekenhuis, Den Bosch); P.H.M. Reemst, MD (Máxima Medisch Centrum, Veldhoven); E.C.J. Consten, MD, PhD (Meander Medisch Centrum, Amersfoort); S.A. Koopal, MD (Leeuwarden Medical Centre, Leeuwarden); P.A. Neijenhuis, MD, ScS (Alrijne Ziekenhuis, Leiderdorp); G.H.H. Mannaerts, MD, PhD (Sint Franciscus Gasthuis, Rotterdam); A.B. Smits, MD (St. Antonius Ziekenhuis, Nieuwegein); D.H.C. Burger, MD (Elisabeth-Tweesteden Ziekenhuis, Tilburg); M.G.A. van IJken, MD, PhD (Van Weel-Bethesda Ziekenhuis, Dirksland); P. Poortman, MD, PhD (Waterlandziekenhuis, Purmerend); M.J.P.M. Govaert, MD (Westfriesgasthuis, Hoorn); W.A. Bleeker, MD, PhD (Wilhelmina Hospital Assen); F.C. Den Boer, MD, PhD (Zaans Medical Center); F. Wit, MD (Ziekenhuis Tjongerschans, Heerenveen); Ph. M. Kruyt, MD (Ziekenhuis Gelderse Vallei, Ede); A. Mearadji, MD, PhD (Bravis Ziekenhuis, Bergen op Zoom); J.T. Heikens, MD, PhD (Ziekenhuis Rivierenland, Tiel)

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 -radiotherapy*	None	446	16.0%	39	32.0%	<0.001
	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).

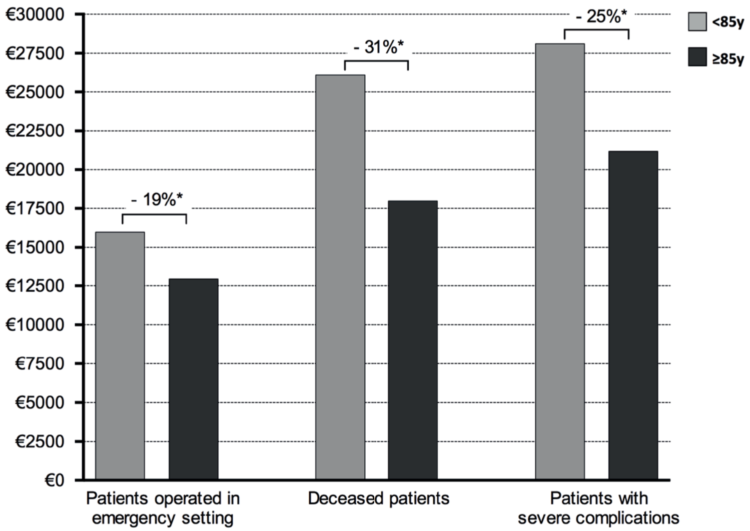


Figure 1. Lower hospital costs for oldest old patients operated in emergency setting and with a complicated course
Total hospital costs of resections in emergency setting, resections leading to death and resections leading to severe complications stratified by age group. * Significant difference, p 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

ACKNOWLEDGEMENT

We would like to thank G.J. Liefers, MD, PhD (Department of Surgery, Leiden University Medical Center, Leiden, The Netherlands) for sharing his expertise on treating oldest old surgical patients and for reviewing our work.

REFERENCES

1. *World report on Ageing And Health.* World Health Organisation;2015.
2. Hewitson P, Glasziou P, Watson E, Towler B, Irwig L. Cochrane systematic review of colorectal cancer screening using the fecal occult blood test (hemoccult): an update. *Am J Gastroenterol.* 2008;103(6):1541-1549.
3. Schilling PL, Dimick JB, Birkmeyer JD. Prioritizing quality improvement in general surgery. *Journal of the American College of Surgeons.* 2008;207(5):698-704.
4. Govaert JA, Fiocco M, van Dijk WA, et al. Costs of complications after colorectal cancer surgery in the Netherlands: Building the business case for hospitals. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2015;41(8):1059-1067.
5. Verweij NM, Schiphorst AH, Maas HA, et al. Colorectal Cancer Resections in the Oldest Old Between 2011 and 2012 in The Netherlands. *Ann Surg Oncol.* 2016;23(6):1875-1882.
6. Kvasnovsky CL, Adams K, Sideris M, et al. Elderly patients have more infectious complications following laparoscopic colorectal cancer surgery. *Colorectal disease : the official journal of the Association of Coloproctology of Great Britain and Ireland.* 2016;18(1):94-100.
7. Surgery for colorectal cancer in elderly patients: a systematic review. Colorectal Cancer Collaborative Group. *Lancet.* 2000;356(9234):968-974.
8. Neuman HB, O'Connor ES, Weiss J, et al. Surgical treatment of colon cancer in patients aged 80 years and older : analysis of 31,574 patients in the SEER-Medicare database. *Cancer-Am Cancer Soc.* 2013;119(3):639-647.
9. Srebniak MI, Diderich KE, Govaerts LC, et al. Types of array findings detectable in cytogenetic diagnosis: a proposal for a generic classification. *European journal of human genetics : EJHG.* 2014;22(7):856-858.
10. Rijksoverheid. *Rapport 'De zorg: hoeveel extra is het ons waard?'.* The Dutch Ministry of Health Welfare and Sport;2012.
11. Govaert JA, van Dijk WA, Fiocco M, et al. Nationwide Outcomes Measurement in Colorectal Cancer Surgery: Improving Quality and Reducing Costs. *Journal of the American College of Surgeons.* 2016;222(1):19-29 e12.
12. Van Leersum NJ, Snijders HS, Henneman D, et al. The Dutch surgical colorectal audit. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2013;39(10):1063-1070.
13. Performation. http://www.performation.com.
14. Kaplan RS, Anderson SR. Time-driven activity-based costing. *Harvard business review.* 2004;82(11):131-138, 150.
15. Mercier G, Naro G. Costing hospital surgery services: the method matters. *PloS one.* 2014;9(5):e97290.
16. Porter ME, Lee TH. The Strategy That Will Fix Health Care. *Harvard business review.* 2013;91(12):24-24.
17. Henneman D, van Leersum NJ, Ten Berge M, et al. Failure-to-rescue after colorectal cancer surgery and the association with three structural hospital factors. *Ann Surg Oncol.* 2013;20(11):3370-3376.
18. Altman DG. *Practical Statistics for Medical Research.* Chapman and Hall/ CRC; 1991.

19. Kolfschoten NE, Wouters MW, Gooiker GA, et al. Nonelective colon cancer resections in elderly patients: results from the dutch surgical colorectal audit. *Digestive surgery.* 2012;29(5):412-419.

20. Snijders HS, Kunneman M, Bonsing BA, et al. Preoperative risk information and patient involvement in surgical treatment for rectal and sigmoid cancer. *Colorectal disease : the official journal of the Association of Coloproctology of Great Britain and Ireland.* 2014;16(2):O43-49.

21. Ghignone F, van Leeuwen BL, Montroni I, et al. The assessment and management of older cancer patients: A SIOG surgical task force survey on surgeons' attitudes. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2016;42(2):297-302.

22. Buigues C, Juarros-Folgado P, Fernandez-Garrido J, Navarro-Martinez R, Cauli O. Frailty syndrome and pre-operative risk evaluation: A systematic review. *Archives of gerontology and geriatrics.* 2015;61(3):309-321.

23. Dekker JW, Gooiker GA, Bastiaannet E, et al. Cause of death the first year after curative colorectal cancer surgery; a prolonged impact of the surgery in elderly colorectal cancer patients. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2014;40(11):1481-1487.

24. Dekker JW, van den Broek CB, Bastiaannet E, van de Geest LG, Tollenaar RA, Liefers GJ. Importance of the first postoperative year in the prognosis of elderly colorectal cancer patients. *Ann Surg Oncol.* 2011;18(6):1533-1539.

25. Ridic G, Gleason S, Ridic O. Comparisons of health care systems in the United States, Germany and Canada. *Materia socio-medica.* 2012;24(2):112-120.

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

CHAPTER 9

J.A. Govaert

W.A. van Dijk

M.W.J.M. Wouters

VALUE-BASED REIMBURSEMENT: A TOOL FOR FURTHER QUALITY IMPROVEMENT IN HEALTHCARE?

Nederlands Tijdschrift voor Geneeskunde 2017

ENGLISH SUMMERAY

A recent Dutch publication identified that costs of surgical treatment of colorectal carcinoma strongly differed between different risk-groups of patients. Those cost-differences were mainly due to an increased risk of complications when operating frail patients, subsequently resulting in high hospital costs. This might have its financial impact for healthcare providers treating high volume of frail patients. Also this could support 'cherry-picking of low-risk patients' by healthcare providers, which might on its own not be a bad development, however the reimbursement is not adjusted accordingly.

This article discusses this shortcoming of the current Dutch reimbursement system and suggests how a differentiated reward -where reimbursement is aligned with the risk profile of the patient- could serve as a tool to further quality improvement in healthcare. Current clinical registries may provide the necessary patient characteristics for allocating the right risk profiles and may also contribute to the ultimate goal: reimbursement based on outcome.

Nederland staat in de top vijf van de duurste zorgsystemen in Europa [1]. Inzicht in kwaliteit en kosten is cruciaal om te bepalen of onze zorg waardevol is en tegen een redelijke prijs wordt geleverd. Daarnaast geeft dit de mogelijkheid om de beloning af te gaan stemmen op geleverde kwaliteit. Aan de hand van de chirurgische behandeling van het colorectaal carcinoom willen wij dit toelichten.

Inzicht in kwaliteit en kosten

Sinds de oprichting van de Dutch Institute for Clinical Auditing (DICA) zijn voor verschillende aandoeningen klinische uitkomsten van zorg inzichtelijk geworden [2]. Door deze uitkomsten uniform en transparant te meten zijn zorgverleners in staat hun uitkomsten te vergelijken, expertise te delen en uiteindelijk de uitkomsten verder te verbeteren [3]. Dat dit bijdraagt aan een duurzame gezondheidszorg is onlangs aangetoond in de Dutch Value Based Healthcare (DVBHC) study voor de chirurgische behandeling van het colorectaal carcinoom. In deze studie werden op patiënt-niveau gegevens van de Dutch Surgical Colorectal Audit (DSCA) van 29 Nederlandse ziekenhuizen gekoppeld met financiële gegevens. Hierin werd gezien dat in drie jaar tijd (2010-2012) de mortaliteit en gecompliceerd beloop daalde met respectievelijk 20% en 29%. Tegelijkertijd namen de kosten in dezelfde periode met 9% af, van 14.237 euro naar 13.145 euro per patiënt. Ziekenhuizen die het percentage ernstige postoperatieve complicaties niet konden verminderen (n = 7) waren in deze periode 390 euro per patiënt duurder uit. Ziekenhuizen die het percentage ernstige complicaties zagen afnemen met 0 tot 10% (n = 12) of meer dan 10% (n = 10) waren respectievelijk 1.353 euro en 2.158 euro per patiënt goedkoper. Wanneer alle deelnemende ziekenhuizen (n = 29) zouden presteren als de ‘best practice groep’ zou er in drie jaar tijd meer dan 20 miljoen kunnen worden bespaard [4]. Deze ontwikkelingen geven hoop dat wij steeds meer inzicht krijgen en kunnen sturen op de waarde van zorg, een ontwikkeling die vorig jaar in dit tijdschrift nog ter discussie werd gesteld [5].

Een vervolganalyse van de DVBHC study heeft geleid tot een recente publicatie over kostenverschillen tussen colorectale patiënten met een variërend risico profiel [6]. Om inzicht te krijgen in verschillen tussen risicogroepen werd in deze publicatie, naast stratificatie voor operatietechniek (open versus laparoscopisch), ook gekeken naar tumorlocatie (colon versus rectum), leeftijd (<75 jaar versus ≥75 jaar) en ASA classificatie (ASA I-II versus ASA III-IV). Verschil in ziekenhuiskosten tussen de subgroepen varieerde van €10.474 voor 'laparoscopische, ≥75jaar, ASA I-II colon' patiënten tot €20.865 voor 'laparoscopische, <75jaar, ASA III-IV rectum' patiënten (een verschil van 99%).

Het verschil van 99% tussen de duurste en goedkoopste subgroep was grotendeels te verklaren door het verschil in percentage ernstige complicaties. Dit werd voornamelijk bepaald, naast de keuze voor operatietechniek, door patiëntkarakteristieken, iets waar een zorgaanbieder maar beperkt (tot geen) invloed op heeft. Deze grote kostenverschillen geven aanleiding om te denken dat verdere doelmatigheidswinst in Nederland mogelijk zou kunnen zijn door het sturen op en het belonen van kwaliteit. Dit beloningssysteem zou niet alleen rekening moeten houden met de uitkomsten van geleverde zorg maar ook met verschillen in 'case-mix' tussen de ziekenhuizen [7]. Helaas is dit momenteel (nog) niet het geval.

Huidig declaratie systeem

Zorgaanbieders dienen jaarlijks per zorgproduct de verkoopprijzen in bij het DBC Informatie Systeem (DIS) waarna de Nederlandse Zorg Autoriteit (NZA) een landelijke gemiddelde berekent. Hierbij worden een aantal regels gehanteerd, waaronder het uitsluiten van de goedkoopste 10% en de duurste 10% verkoopprijzen voor de berekening [8]. De verkoopprijs voor de chirurgische behandeling van het colorectaal carcinoom is enkel gebaseerd op onderscheid tussen de lengte van opname (tot 28 dagen versus 28 dagen en langer) of de toepassing van HIPEC, een intra-operatieve behandeling met chemotherapie na cytoreductie van peritoneale metastasen bij een geselecteerde groep patiënten. De landelijk gemiddelde verkoopprijs van een colorectale ingreep zonder HIPEC, veruit het meest voorkomende zorgproduct, verschilt €19.835 (bijna 200%) tussen een korte en lange opnameduur (Tabel 1).

Tabel 1. Gemiddelde landelijke verkoopprijs (2014) berekend door de Nederlandse Zorg Autoriteit (NZA)

Zorgproduct	Beschrijving	Opname-duur	Gemiddelde verkoopprijs
29199032	Uitgebreide operatie aan het maagdarmkanaal met maximaal 28 verpleegdagen bij kanker van dikke darm of endeldarm	<28	€10.310
29199033	Uitgebreide operatie aan het maagdarmkanaal met meer dan 28 verpleegdagen bij kanker van dikke darm of endeldarm	≥28	€30.175

Data verkregen via www.opendisdata.nl.

Kostprijzen

Kostprijzen zijn de daadwerkelijke kosten die tijdens een behandeling worden gemaakt. Bij veel ziekenhuizen ontbreekt het aan representatieve kostprijzen omdat dit buiten kerntaak van ziekenhuizen valt. Het correct toekennen van kosten aan deze handelingen (een verpleegdag, CT scan of operatieve ingreep) is dan ook een lastige exercitie en vaak worden ziekenhuizen geassisteerd door externe consultants. De zorgaanbieder probeert zijn verkoopprijs vaak hoger te houden dan de kostprijs zodat hij een marge kan maken. In sommige gevallen kan de zorgaanbieder besluiten om een zorgproduct tegen een lagere prijs te verkopen onder druk van de zorgverzekeraar of om zo de concurrentiepositie te versterken. Omdat inzicht in kosten en kwaliteit belangrijk is om te bepalen waar de juiste zorg wordt geleverd [4]. denken wij dat er hier voor ziekenhuizen nog veel te winnen valt.

In de DVBHC study zijn de financiële gegevens geleverd door het adviesbureau Performation (Bilthoven) [9], dat voor alle 29 ziekenhuizen kostprijzen heeft berekend. Daarmee werd uniformiteit in de kostprijsmethodiek gewaarborgd. Voor dit artikel (Tabel 2) is een deel van de analyse van de publicatie naar kostenverschillen tussen open en laparoscopische colorectale ingrepen herhaald [6]. Alleen de variabele operatietechniek (open of laparoscopisch) is in dit artikel (Tabel 2) weggelaten omdat deze variabele wordt bepaald door de keuze van de chirurg in samenspraak met de patiënt.

Tabel 2A. Kostprijzen gestratificeerd op hoofdgroep

Hoofdgroep							
Locatie	Leeftijd	ASA	**Aantal**	**Sterfte**	**Gecompliceerd beloop**	**Opname ≥28 dagen**	**Gemiddelde kostprijs**
Colon	-	-	4202	3,1%	18,2%	5,0%	€12.040
Rectum	-	-	2328	1,8%	25,3%	7,8%	€15.034

Tabel 2B. Kostprijzen gestratificeerd op subgroep (oplopend gesorteerd).

Subgroep							
Locatie	Leeftijd	ASA	**Aantal**	**Sterfte**	**Gecompliceerd beloop**	**Opname ≥28 dagen**	**Gemiddelde kostprijs**
Colon	<75	ASA I-II	2072	0,6%	14,1%	3,8%	€10.960
Colon	≥75	ASA I-II	1048	3,8%	18,5%	5,3%	€11.388
Rectum	<75	ASA I-II	1511	0,5%	21,7%	5,8%	€13.638
Colon	<75	ASA III-IV	358	3,4%	21,8%	6,1%	€14.687
Colon	≥75	ASA III-IV	724	9,3%	27,6%	7,2%	€14.767
Rectum	≥75	ASA I-II	422	2,1%	27,7%	10,2%	€15.731
Rectum	≥75	ASA III-IV	210	8,6%	36,7%	14,3%	€19.094
Rectum	<75	ASA III-IV	185	3,2%	35,7%	11,4%	€20.242

Data verkregen uit de Dutch Value Based Healthcare Study. Ziekenhuiskosten van electieve colorectale ingrepen zijn gemeten vanaf operatie tot en met 90 dagen na ontslag, exclusief specialisten honorarium, en kosten van medicatie/ dialyse (zie referentie 4).

Verschil tussen verkoopprijs en kostprijs

Het absolute verschil tussen de verkoopprijs en de kostprijs in dit artikel is onder andere te verklaren doordat de kosten anders zijn berekend. De financiële uitkomsten in de DVBHC study zijn bijvoorbeeld gemeten tot 90 dagen na ontslag en bevatten alle ziekenhuiskosten. Daarentegen is de gemiddelde verkoopprijs, berekend door de NZA, gemeten tot 42 dagen na ontslag en bevat alleen de DBC gerelateerde kosten. Daarom hebben wij in Tabel 3 naar de verhouding tussen de verschillende patiëntgroepen gekeken. Hierbij zien wij dat voor rectum chirurgie de kostprijs 25% (€2.994) hoger ligt dan voor colon chirurgie (Tabel 3A). De verklaring hiervoor is dat rectum chirurgie over het algemeen als complexer wordt beschouwd met een hogere kans op complicaties (en daardoor langere ligduur) dan colon chirurgie [3]. Kijken we vervolgens voor rectum chirurgie naar de berek-

ende gemiddelde verkoopprijs van de NZA dan ligt het bedrag bij rectum chirurgie gemiddeld slechts 5% (€556) hoger dan bij colon chirurgie (door de iets hogere -2.8%- verlengde opnameduur van meer dan 28 dagen, Tabel 3A).
Bij de verdere subgroep analyse is ook rekening gehouden met leeftijd en co-morbiditeit. Hier loopt het verschil in kostprijs tussen de goedkoopste subgroep (colon, <75 jaar, ASA I-II) en de duurste subgroep (rectum, <75 jaar, ASA III-IV) op tot 85% (€8.839). Kijken we bij dezelfde twee subgroepen naar de gemiddelde verkoopprijzen, dan zien we dat het verschil terugloopt naar 14% (€1.510, Tabel 3B).

Tabel 3A. Relatief verschil in kostprijs en verkoopprijs tussen de twee hoofdgroepen

Hoofdgroep		
Locatie	**Op basis van gemiddelde kostprijs**	**Op basis van gemiddelde verkoopprijs**
Colon	€12.040	€11.303 (95,0% x €10.310) + (5,0% x €30.175)
Rectum	€15.034	€11.859 (92,2% x €10.310) + (7,8% x €30.175)
Verschil	***25%***	***5%***

Tabel 3B. Relatief verschil in kostprijs en verkoopprijs tussen de twee meest verschillende subgroepen (zie tabel 2b)

Subgroep				
Locatie	Leeftijd	ASA	**Op basis van gemiddelde kostprijs**	**Op basis van gemiddelde verkoopprijs**
Colon	<75	ASA I-II	€10.960	€11.065 (96,2% x €10.310) + (3,8% x €30.175)
Rectum	<75	ASA III-IV	€20.242	€12.575 (88,6% x €10.310) + (11,4% x €30.175)
Verschil			***85%***	***14%***

Uitkomsten in tabel 3a zijn berekend door de uitkomsten van tabel 1 en 2 te combineren.

De tekortkomingen

Zoals hierboven weergegeven legt de huidige manier van belonen verschillende knelpunten bloot:
1). In het huidige systeem wordt geen onderscheid gemaakt tussen hoog dan wel laag risicosubgroepen. Dit zou kunnen leiden tot ‘cherry picking’ waarbij specifieke zorginstellingen (bijv. een zelfstandig behandelcentrum) zouden kunnen besluiten alleen laag-risico patiënten te opereren zoals de ASA I-II subgroepen (weergegeven

in Tabel 2B). Hoog risicopatiënten zouden in dit scenario worden doorverwezen naar bijvoorbeeld tertiaire ziekenhuizen. Hierdoor kan de winstmarge van de zorginstelling niet zozeer bepaald worden door het reduceren van complicaties maar door selectie aan de poort. Voor 'gewone' ziekenhuizen is deze selectie minder vanzelfsprekend omdat selectie aan de poort vaak de professionele verantwoordelijkheid raakt. Niettemin is dit door ingestelde volumenormen voor bijvoorbeeld rectum chirurgie ook in zekere mate voor deze ziekenhuizen van toepassing. Op zichzelf geen slechte ontwikkeling, maar dit veroorzaakt case-mix verschillen tussen ziekenhuizen waarop het beloningssysteem niet is ingericht.
2). Wellicht net zo belangrijk is dat in het huidige systeem de financiële prikkel tot het verbeteren van kwaliteit ontbreekt. In theorie bestaan er zelfs perverse prikkels waarbij complicaties kunnen leiden tot een hogere beloning. Immers, op basis van de 28 dagen regel kunnen colorectale patiënten met een lange opnameduur een 200% hoger bedrag opleveren dan patiënten met een voorspoedig herstel (zie Tabel 1). Dit is iets wat in meer en mindere maten ook geldt voor andere diagnoses [8]. Nederland staat hier in niet op zichzelf, ook in Amerika zijn er situaties waar het hebben van meer complicaties kan leiden tot hogere inkomsten [10]. Tevens houd het huidige systeem de zorgaanbieder slechts 42 dagen verantwoordelijk voor heropnames, wat korte termijn denken in de hand kan werken. Het opheffen van een tijdelijk stoma (veelal pas enkele maanden na de ingreep) valt hier bijvoorbeeld niet onder [11].

Uitkomstenbekostiging

Om aan bovenstaande tekortkomingen tegemoet te komen zou idealiter de bekostiging afgestemd worden op behaalde uitkomsten. Hierbij moet gecorrigeerd worden voor zorgzwaarte en moeten zorginstellingen (financieel) risico dragen voor de langere termijn uitkomsten van behandelde patiënten. Verbeteren van uitkomsten levert dan financieel voordeel op, wat de doelen van zorgverleners, zorgaanbieders, verzekeraars én patiënten op één lijn brengt. Zorgaanbieder en zorgverzekeraar zouden dan afspraken moeten maken over de te behalen (verbetering in) uitkomsten en bijbehorende financiële beloning. Investeren in kwaliteitsverbetering wordt dan ook financieel aantrekkelijk, in plaats van een last zoals dat nu soms wordt gezien. Tot slot zijn er gedachten -onder andere binnen Value Based Healthcare theorie - dat verdere doelmatigheid kan worden bereikt door de hele keten van zorg op te nemen in de beloning, inclusief preventie [12]. Uitkomstenbekostiging over de keten van zorg heeft onder andere in de Stockholm regio voor indrukwekkende resultaten gezorgd. Orthopedische chirurgen, fysiotherapeuten en zorgverzekeraars hebben samen afspraken gemaakt voor de behandeling van knie- en heup artrose. Hierbij verdwenen de wachtlijsten voor knie- en heup operaties, lange termijn uitkomsten verbeterden en kosten werden gereduceerd [13]. Minister Schippers heeft eenzelfde doel voor ogen en zij gaf aan uitkomstenbekostiging uiterlijk in 2020 te willen introduceren. Hierdoor zouden zorgaanbieders gestimuleerd worden om gezamenlijk optimale zorgresultaten te behalen en gelijktijdig de kosten te beheersen [14].

De overgang naar uitkomstbekostiging zal in Nederland niet zomaar geregeld zijn en zoals minister Schippers aangeeft zou dit stapsgewijs moeten worden doorgevoerd [14]. Een eerste stap die wij voorstellen is het gedifferentieerd belonen. Zoals het voorbeeld over de chirurgische behandeling van het colorectaal carcinoom laat zien zou de zorgverzekeraar laag complexe subgroepen minder moeten belonen, en hoog complexe subgroepen meer moeten belonen (hiermee inspelend op tekortkoming 1). Zorgaanbieders die zich richten op hoog risico subgroepen krijgen hierdoor meer financiële ruimte om (kostbare) complicaties op te vangen. Een betere verdeling van de vergoeding zou er toe moeten leiden dat goed presterende ziekenhuizen geld over houden, ongeacht de zorgzwaarte van de patiënt. Dit geeft mogelijkheden om te kunnen investeren in kwaliteitsinitiatieven dat weer moet leiden tot nog betere zorg voor de patiënt. Een voordeel is dat op korte termijn een eerste stap gemaakt kan worden omdat de benodigde gegevens al beschikbaar zijn. Immers, klinische registraties zoals die van de DICA houden zeer gedetailleerd de patiënt en/of tumor karakteristieken bij voor noodzakelijke case-mix correctie. Tevens bieden de op uniforme wijze gemeten uitkomsten van deze registraties een mogelijkheid voor het implementeren van het uiteindelijke doel: belonen op basis van uitkomst van geleverde zorg.

CONCLUSIE

Het voor zorgverleners inzichtelijk maken van uitkomsten op patiëntniveau heeft aantoonbaar geleid tot betere zorg en lagere kosten. Een volgende stap naar meer doelmatige zorg zou het implementeren van uitkomstenbekostiging kunnen zijn. Aangezien dit niet met een 'big bang' dient te gebeuren stellen wij als eerste stap het gedifferentieerd belonen voor, waarbij onderscheid wordt gemaakt tussen verschillen in zorgzwaarte tussen zorgaanbieders.

DANKWOORD

De auteurs willen Sander Steenhuis (promovendus bij het Talma Instituut) en Martijn van Schaik (coördinator zorgverkoop Antoni van Leeuwenhoek) bedanken voor hun bijdrage aan het artikel. Daarnaast willen de auteurs alle deelnemende chirurgen van de Dutch Value Based Healthcare study bedanken voor het gebruik van de DVBHC study database.

REFERENTIES

1. OECD. Health at a Glance: Europe 2014. 2014; http://www.oecd.org/health/health-at-a-glance-europe-23056088.htm. Accessed 25-09-2016.
2. Dutch Institute for Clinical Auditing. http://www.dica.nl. Accessed 06-10-2016.
3. Van Leersum NJ, Snijders HS, Henneman D, et al. The Dutch surgical colorectal audit. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2013;39(10):1063-1070.
4. Govaert JA, van Dijk WA, Fiocco M, et al. Nationwide Outcomes Measurement in Colorectal Cancer Surgery: Improving Quality and Reducing Costs. *Journal of the American College of Surgeons.* 2016;222(1):19-29 e12.
5. Mackenbach JP. [What are the health benefits of the most expensive healthcare system in Europe?]. *Nederlands tijdschrift voor geneeskunde.* 2015;159:A9433.
6. Govaert JA, Fiocco M, van Dijk WA, et al. Multicenter Stratified Comparison of Hospital Costs Between Laparoscopic and Open Colorectal Cancer Resections: Influence of Tumor Location and Operative Risk. *Annals of surgery.* 2016.
7. Kolfschoten NE, Marang van de Mheen PJ, Gooiker GA, et al. Variation in case-mix between hospitals treating colorectal cancer patients in the Netherlands. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2011;37(11):956-963.
8. Nederlandse Zorg Autoriteit. 2016; http://www.opendisdata.nl. Accessed 24-09-2016.
9. Performation. http://www.performation.com. Accessed 10-10-2016.
10. Eappen S, Lane BH, Rosenberg B, et al. Relationship between occurrence of surgical complications and hospital finances. *Jama.* 2013;309(15):1599-1606.
11. Snijders HS, van Leersum NJ, Henneman D, et al. Optimal Treatment Strategy in Rectal Cancer Surgery: Should We Be Cowboys or Chickens? *Ann Surg Oncol.* 2015;22(11):3582-3589.
12. Michael E. Porter RSK. How to pay for health care. *Harvard business review.* 2016;94(7/8).
13. Porter ME, Marks CM, Landman ZC. *OrthoChoice: Bundled Payments in the County of Stockholm.*: Harvard Business School;2014. 714515-PDF-ENG.
14. Schippers EI. *Kamerbrief met reactie op artikel invoering van de uitkomstbekostiging per 2020.* 23-06-2015 2015.

CHAPTER 10

J.A. Govaert

DISCUSSION AND FURTHER PERSPECTIVES

DISCUSSION

Ever since the publication of Michael Porters' book 'redefining healthcare: creating value based competition on results' [1], health care providers have been developing frameworks for realigning the delivery of health care around value for patients. Since challenges for obtaining a sustainable healthcare system in the future include dealing with advances in technology, availability of expensive medications, chronic illness and ageing, it seems unavoidable to re-evaluate the way we have been providing care to our patients.

Surgical auditing and hospital costs

With the continuous rise of healthcare costs, healthcare providers, insurance companies, governments, and patients demand for information and transparency on performance of hospitals. Surgical audits are primarily initiated to monitor outcomes in order to reduce variation between institutions and improve quality of care [2,3]. Although frequently assumed, evidence of surgical auditing as a tool to reduce hospital costs remains scarce. In **chapter 2** [4] we describe the results of a systematic review: of more than 3600 investigated manuscripts on effects of surgical auditing, only six manuscripts reported a relationship between surgical auditing and hospital costs. All six showed a positive effect of surgical auditing on reducing costs. The biggest reduction was seen for the more complex procedures, probably because prevention of adverse events in these procedures might be of greater clinical [5] and therefore financial importance. Since auditing is a time consuming effort [6], the question remains how auditing will effect outcomes –and costs- of 'high-volume low-complex' procedures, like procedures related to inguinal hernia and hip fractures. Also a general note of caution should be made regarding publication bias when performing a review of the literature: studies showing negative outcomes, in our case of surgical auditing, might be less likely submitted for publication by the authors.

Conclusions of our systematic review were supported by the findings from the DVBHC-study. In **chapter 3** [7] we describe the relationship between severe complications and hospital costs for 29 hospitals participating in the Dutch Surgical

Colorectal Audit (DSCA). Between 2010 and 2012, the participating hospitals reduced their severe complications by 20%, their mortality rate by 29% and simultaneously hospital costs by eight percent. Moreover, an inverse relation between severe complication rate and hospital costs was identified and hospitals with the strongest improvement in three years had the strongest cost reduction. The total estimated cost reduction in the three consecutive years was more than €5 million for the participating hospitals. Even more, by combining clinical and financial outcomes we identified 'best practice' hospitals, and therefore providing a realistic goal for all other hospitals. If between 2010 and 2012 all other hospitals in our study performed on the level of the best practice hospitals, the additional savings in this three-year-study would have been more than €20 million (Figure 3 **chapter 3** [7]). When comparing this to the overall Dutch hospitals budget of €23 billion a year, the savings might seem less impressive. However, these results should be interpreted in the light that we analyzed only the surgical part of one clinical diagnosis, leaving room for more savings, for example when the full potency of other registries is revealed as well. One might argue that ascribing improved quality of care (and cost reduction) to surgical auditing might be related to other factors: for example possible occurrences of secular trends not registered in the audit or increased rate of laparoscopic surgery. However, when comparing mortality of other oncologic diagnosis in the Netherlands, like gastric cancer, no reduction in post-operative mortality was found until the introduction of the Dutch Upper Gastrointestinal Cancer Audit [8]. Moreover, a reduction of mortality and/ or complications can only be achieved when key data regarding clinical outcomes is available: without this data, health care organizations are flying blind in deciding what should be targets for quality improvement initiatives or in deciding which 'peer-hospitals' could serve as best practice hospitals.

Since registering and data verification is a cost and time consuming exercise [6], we presented a business case in **chapter 4** [9]. Despite the additional time -and therefore costs- of data registration and data verification, we show that participating in the DSCA resulted in overall cost reduction of € 80,393 in three years (for a hospital yearly volume of 100 procedures, supplemental table 2, **chapter 4** [9]). Moreover, we describe in this chapter the tremendous impact of severe complications after colorectal cancer surgery on hospital costs: the top five percent most expensive patients were responsible for 23% of the total cost and additional costs of patients with complications was more than 30% of the total budget (figure 1, **chapter 4** [9]). However, assuming direct relationships between single complications and costs may not be appropriate since some costs are not likely to be affected by a reduction in complications in the short term. For example overhead costs of the intensive care unit will more or less still exist, regardless of the number of patients admitted to such unit. Also costs of staffing will not change on the short term by a decrease in complications, since most of the staff is employed by the hospital based on long-term contracts.

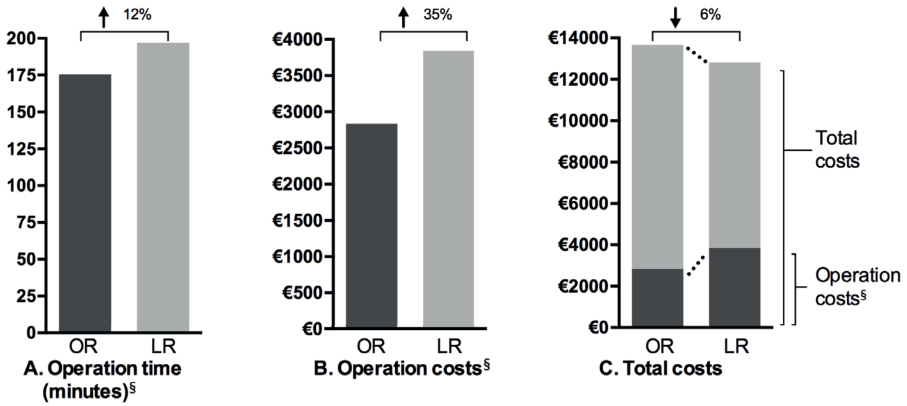


Figure 1. Laparoscopy vs open colorectal cancer resection (unpublished figure)
All elective T1-4N0-2M0-2 stage colorectal cancer patients were included. Laparoscopic resection (n=4237) was associated with longer operation time (A) and higher operation costs (B) as compared to open resection (n=3937). Total costs were lower for laparoscopic resection as compared to open resection (C). Arrow represents relative difference of unadjusted outcomes. Abbreviations: LR, laparoscopic resection; OR, open resection. § Time and costs of primary operation only.

Laparoscopic techniques and hospital costs

During the last two decades, laparoscopic resection has developed as a commonly accepted surgical procedure for colorectal cancer. Existing literature showed that 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 to open resection [10-13], although two recent RCTs question its routine use for rectal cancer [14,15]**.** Surprisingly, its effect on hospital costs is less thoroughly investigated. Most of the cost-studies were based on randomized controlled trials (RCTs) [16], which are known to describe outcomes of a selected group of patients operated in specialized (referral) centers [17] and their limitations should be acknowledged, especially regarding external validity [18]. 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 and therefore proxies of actual costs are used, like DRG's or insurance claim data (see cost calculations) [19].

In order to analyze the effect of a laparoscopic approach on hospital costs, our first attempt was to analyze a pooled group of all elective T1-4N0-2M0-2 stage colorectal cancer patients. In this first study, differences in patient characteristics were taken into account by performing multivariate analysis (Figure 1). However, after discussing our data with experts in the field [20], we believed that multivariate analyses would not correct for all (unknown) factors, which may have influenced the decision to perform open or laparoscopic surgery. As recently published by our group, sub-group analyses might provide better insight in clinically relevant subgroups and be of more interest for health care providers and/or payers [21]. Therefore, we reviewed our data using sub-group analyses based on tumor location (colon vs rectum) and operative risk (age <75 years vs >75 years and ASA I-II vs ASA III-IV). Also, we selected T1-3N0-2M0 stage patients operated in an elective setting only. As shown in **chapter 5** [22], elective laparoscopic resection in all colon cancer subgroups resulted in lower hospital costs due to less severe complications and lower length of hospital stay. For all rectal cancer subgroups, laparoscopy resulted in higher hospital costs. This was probably due to the high rate of stoma construction in rectal cancer surgery (approximately 80%, Table 1 **chapter 5** [22]) and therefore eliminating advantages seen after laparoscopic colon resections, like early discharge. Surprising was the tremendous variation in average total hospital costs between the clinical subgroups, ranging from €10,474 (≥75year ASA I-II laparoscopic colon cancer patients) to €20,865 (<75year ASA III-IV laparoscopic rectal

cancer patients), which is a 99% difference. This significant variation between the subgroups should be an incentive for Dutch payers and/or healthcare providers to evaluate current reimbursement systems (see **chapter 9** [23]).
Earlier studies analyzing differences in costs between open and laparoscopic procedures showed univocal outcomes. An important determinant in these studies might be that often no distinction between colon and rectal procedures was made [16,24,25]. Probably this might be due to lower number of patients included in these studies making pooled analyses necessary. However, interpretation of those conclusions is difficult [16,24,25], 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.
Therefore, besides quality improvement, the availability of large number of patients in clinical registries underlines their importance as a robust source of data for research. The availability of large number of patients enables sub-group analyses, which - depending on the research question- might reveal better clinical insights as compared to multivariate analyses. Moreover, detailed data from nationwide covered clinical registries include information of patients often excluded from RCT's, and therefore can address new research questions regarding patient care, new treatment modalities and the way it is financed.

Nowadays, more than 70% of all colon and 85% of all rectum cancer resections in the Netherlands are performed through laparoscopy [26]. The vast majority of these laparoscopic procedures are performed using conventional laparoscopic techniques. A relatively new approach for operating colorectal cancer is the single-port laparoscopy (SPL). In 2010 the gastrointestinal surgeons of the Jeroen Bosch Hospital started with the introduction of SPL for less-complex abdominal procedures [27,28], resulting in the first SPL colorectal cancer resections in 2011. Since little is known about the costs of applying SPL, we performed a single-center cost-analysis of SPL in 2011 and 2012 (**chapter 6** [29]). Although average costs of SPL over two years were higher as compared to conventional laparoscopy, a 35% decrease in hospital costs was seen for single port procedures after the introduction year resulting in comparable costs as conventional laparoscopy. Moreover, although SPL

is a relatively new technique, this study showed that implementation of SPL could be save since there were no significant differences in mortality and/ or severe complications as compared to conventional laparoscopy. Advantages of single-port surgery include the use of a single incision. This single incision is larger than the incision of a conventional port (5 or 12mm), and one of the concerns after for example cholecystectomies might be an increased rate of port side hernias [30]. In the case of a colectomy, the affected bowel cannot be removed through a 12mm port and needs to be removed through a larger incision. Therefore during conventional procedures the 12mm sub-umbilical incision has to be extended (an alternative is the use of a Pfannenstiel incision). In SPL procedures the larger incision for the single port could be used for the removal of the bowel, minimizing the disadvantage of this initial bigger incision.
This chapter used single center data, and the number of SPL procedures was relative small (analyzing 78 SPL procedures versus 189 conventional procedures). Therefore, conclusions of superiority and inferiority between the two procedures cannot be made. However, part of the evaluation of new surgical techniques is assessing its costs, and therefore this chapter should be seen as an impetus for further research in the field of laparoscopic advancements.

High-risk patients and hospital costs

In order to facilitate the discussion of increasing healthcare costs when operating high-risk patients we analyzed the impact on hospitals costs of two specific subgroups suffering from high complications rates. In **chapter 7** [31] we describe that obesity is associated with a significant increase in hospital costs, up to a 22% increase for obesity class ≥2 patients. Earlier studies describing such relationship were conducted in either the relatively obese populations of the United States and New Zeeland [32,33] or the relatively none-obese population of Japan [34]. Our report is the first to describe this relationship for an European country with an intermediate BMI distribution, and our findings should therefore be of use for other countries with an intermediate BMI distribution, like Sweden and France (Figure 2) [35]. Moreover, we show that pre-obesity is associated with a significant lower mortality rate after colorectal cancer

procedures. This so-called 'obesity paradox' was also identified in general surgery [36] however has never been identified for surgical colorectal cancer patients.
In conclusion, obese colorectal cancer patients have an increased risk for both minor and major complications, which highlight the need for targeted quality programs for these patients. Moreover, since obesity is becoming pandemic, obesity-related increase of healthcare costs could be expected worldwide when treating colorectal cancer patients.

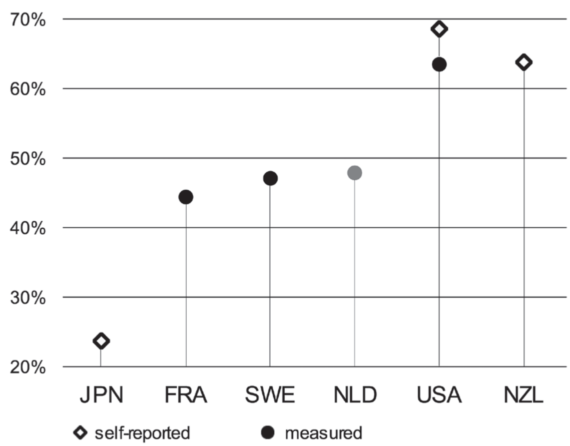


Figure 2. Pre-obese or obese population by country (2012)
Data retrieved from OECD: pre-obese [BMI 25-29,99 kg/m^2] or obese population [BMI > 30 kg/m^2] [35]. Percentage of population ≥15 year is shown. Abbreviations: JPN, Japan. FRA, France. SWE, Sweden. NLD, the Netherlands. USA, United States of America. NZL, New Zealand.

Operating oldest old colorectal cancer patients (≥85 year) has always been part of discussion between health care providers. A recent Dutch study showed a 12% excess mortality for the oldest old colorectal cancer patients in the first year after surgery [37], which is also seen after other major procedures like aorta aneurysm repair [38]. In combination with an increased risk of post-operative complications, one might argue that operating the oldest old for colorectal cancer might result in an impermissible misbalance in hospitals' resource utilization. In **chapter 8** [39] we describe that oldest old (≥85 year) suffered from higher complication and mortality rates as compared to their younger counterparts (Table 2, **chapter 8** [39]). Although in the other chapters of this thesis higher complication rates were associated with higher costs, post-surgery hospital costs of the oldest old did not increase. These lower costs were probably due to faster deterioration or less aggressive treatment when complications occur (Table 3, **chapter 8** [39]). This was indicated by less resource utilization and a higher failure to rescue rate when severe complications occur in the oldest old as compared to patients under 85 years. Since cases registered in the DSCA reflect 'real world' surgical selection, conclusions based on this study emphasizes that (short-term) financial arguments should not play a role in clinical decision making whether to operate the oldest old or not.

Reimbursement and hospital costs

The current Dutch reimbursement system is far from adding 'value' in colorectal cancer surgery [40]. No differences in reimbursement for colorectal cancer surgery exist between tumor location, ASA classification or age. At the moment, differences in reimbursement are mainly based on length of hospitalization (up to 28 days vs more than 28 days, see Table 1) or the use of hyperthermic intraperitoneal chemoperfusion (HIPEC), which is an intra-operative treatment with chemotherapy after cytoreduction of peritoneal metastases in a selected group of patients. It seems fair that hospitals will financially be compensated for longer hospital admissions. Although unlikely, since it might affect the integrity of healthcare providers, this higher reward for longer admissions may also provide a strong perverse stimulus. This more or less applies for the United States of America as well, were Eappen et al. reported that some hospitals have the potential for adverse near-time financial consequences when reducing their post-surgical complications (depending on payer mix) [41].

In **chapter 9** [23] we make a suggestion for a first step to a more sophisticated reimbursement system. The idea arose following the publication of **chapter 5** [22], where actual costs of patients in the different colorectal cancer subgroups differed up to 99%. These differences were based on differences in tumor location, ASA classification, age and operation technique (Figure 1, **chapter 5** [22]). This means that healthcare providers serving relatively high number of frail colorectal cancer patients should be aware of the accompanying increased hospital costs without receiving a proper financially compensation (Table 1, **chapter 9** [23]). The substantial differences in actual costs between the different risk groups, something a healthcare provider cannot influence, highlight the need for a better and fairer reimbursement system.

A new reimbursement system should not be introduced with a 'big bang'. Instead, we propose **in chapter 9** [23] as a first step that colorectal cancer payments should be adjusted for patient and tumor characteristics (for example based on ASA classification, age and tumor location). Hospitals serving low-risk patients will receive a lower reward, therefore discouraging 'cherry picking' and pushing those hospitals to become more efficient. Hospitals serving high-risk patients will receive a higher reward, therefore giving those hospitals the opportunity to develop quality improvement initiatives in order to reduce complication rates. A better distribution of the reimbursement will give all hospitals the opportunity to deliver profitable care, regardless of their patients case-mix. A reasonable (and necessary) next step could be coupling the reward to outcomes of care, such as those available in the DSCA [2], in order to increase value of delivered care [42]. This is also what the Dutch minister of Healthcare has in mind, proposing implementation of outcome reimbursement in 2020 [43].

Analyzing hospital costs

Understanding hospital finances is complex and articles describing accurate translation of resource utilization into costs are scarce. In research, mostly proxies of costs are used, like insurance claim data or costs of drugs related diagnosis to indicate expenditures. One of the best methods to determine actual costs might be activity-based costing at patient level. As outlined by Kaplan, even better is using time-driven activity-based costing (TD-ABC), 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 [44]. 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 [45].

Earlier studies analyzing cost reduction of surgical auditing (**chapter 2** [4]) were hampered by their use of 'fixed' costs of complications. In those studies a decline in complication rate was multiplied by a fixed price of those complications [46,47]. Only Hollenbeak et al. used patient-level cost-calculations based on a standard ratio of cost-to-charges methodology [48]. For the cost-to-charges methodology, costs are estimated as a percentage of hospital charges. Since each hospital department estimated a

cost-to-charges on a yearly basis, the authors admitted that this approach is certainly imperfect for estimating hospital costs [48]. Also multi-center studies analyzing cost differences between open or laparoscopic colorectal resections had their limitations, mainly because of a lack of uniform cost calculations between the individual centers [49]. Populations-based studies analyzing differences between open and laparoscopic colorectal procedures were performed in the United States of America and based on claim data from payers and therefore not reflecting actual hospital costs [19,50].
In this thesis, translation of resource utilisation into costs was performed by Performation, a healthcare consultancy firm providing patient level costing and benchmarking services for more than 100 hospitals across Europe [51]. Performation uses the activity-based costing methodology and where possible TD-ABC to determine actual hospital costs and benchmark products. All in-hospital resources used by the care of a patient (and therefore costs of those patients) are being tracked in the hospital information system and linked to the patients' unique identification number. Since both the DSCA and Performation measure outcomes at patient level, combining these databases at patient level reveals detailed cost information of colorectal cancer treatment leading to compelling steering information (Figure 3).

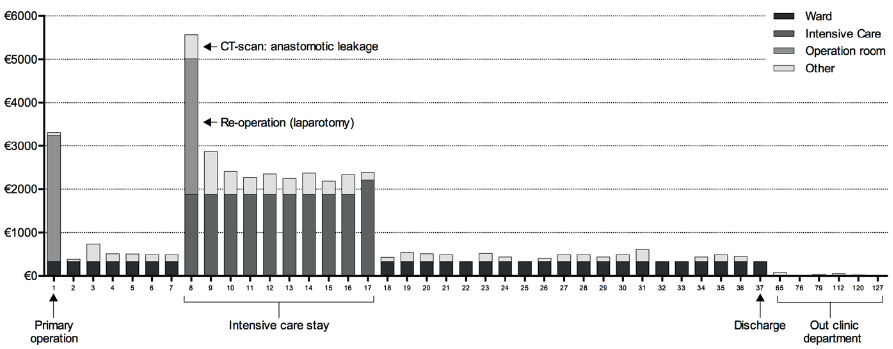


Figure 3. Illustrative picture: hospital costs of a patient with a complicated course
Hospital costs of a 79-year, ASA III, female patient with a caecum cancer undergoing a laparoscopic ileocecal resection (day 1) followed by an anastomotic leakage (day 8). Cost of primary admission (day 1 till day 41) were €42,274. Cost during Q1 (first 90 days after discharge) were €216. Data retrieved from the DVBHC-study.

10

FURTHER PERSPECTIVES

Payment systems

From a macro-economic perspective healthcare has a bad track record when it comes to reducing costs. One of the future challenges will be determining through which system we are going to pay for our healthcare delivery in the next decades [52]. Experts in the field agree that the current Dutch leading system with 'fixed annual budgets' for providers is outdated since budgets are disconnected from the actual patient need that arises during the year. This system also leads to waiting lists and creates pressure on both healthcare providers and payers at the end of the year when predetermined budgets are exceeded [53]. Also the system in the United States, 'fee for service', is far from perfect. It fosters 'eat what you kill' mentality thereby fueling waste by rewarding quantity and not quality of care.

None of the healthcare innovations during the last decades have led to considerable costs reductions, and therefore skepticism remains why a value based system will. For example, what if we are able to decrease failure to rescue rate for colorectal cancer patients by 50 percent? Although one might consider this as improvement in quality, this implies that more patients suffering from severe complications will survive and therefore generate more hospital costs. Eventually these patients will die from the same (or other diseases) in the future and therefore shifting present costs to costs in the future. This underlines that not all improvement in healthcare automatically leads to a reduction in costs, however when focused on the right outcomes it will, as seen in **chapter 3** [7] **and 4** [9].

Two recent publications in the Harvard Business Review described two leading payment systems that might catalyze development of high-quality care: capitation or bundled payments [42,54]. Suggested by Michael Porter, 'bundled payments' might realign delivery of healthcare even more around value for patients. Bundled payments cover the full care cycle for acute medical conditions, the overall care for chronic conditions for a defined period, or primary and preventive care for a defined patient population. Besides case-mix correction they also have care guarantees that hold providers responsible for avoidable (long-term) complications [42].

As seen for hip and knee replacements in Sweden, bundled payments improved efficiency while improving outcomes for patients [55]. Also incorporating the whole chain of care in the reimbursement could lead to more efficiencies while maintaining quality, as seen in the Dutch ParkinsonNet [56]. Although existing literature sounds promising, further studies are needed to identify if bundled payments will catalyze also further improvement of value in colorectal cancer care. For example, the construction of a defunctioning stoma in rectal cancer surgery might be seen as a risk adverse strategy. However, a recent study showed that a high tendency towards stoma construction did not result in lower overall anastomotic leakage or mortality rates [57]. Since construction of a defunctioning stoma introduces extra costs in the future (e.g. purchase of stoma bags, costs of treating stoma related complications, costs of a re-operation for removing the stoma), rewarding long-term outcomes in colorectal cancer surgery might provide more awareness whether to construct a stoma in the first place.

The other leading model to pay for healthcare is capitation [54]. With a population-based capitated payment healthcare providers are paid a fixed amount for each enrolled person assigned to them, per period of time, whether or not that person seeks care. It should be adjusted for each patient's expected needs and also held providers accountable for high-quality outcomes. Supporters of this system claim that this approach is the only one that would encourage healthcare to improve quality since it fundamentally shifts the role of managing care from insurers to care providers. A major driver behind this is system is that it should reduce all kinds of waste, which is claimed to eat up at least 35% of the healthcare budget [54]. Since there is no robust nationwide evidence for either system yet, the big challenge for the future is to determine which system will support development of a high value care system the most.

Dealing with expensive medication

Another future challenge will be dealing with expensive medications. Recent developments in the field of oncology increased the number of indications for immunotherapy and so called 'targeted therapies'. Immunotherapy is a type of cancer treatment designed to boost the body's natural defenses to fight the cancer. It uses substances either made by the body or in a laboratory (e.g. monoclonal antibodies, vaccines, T-cells) to improve or restore immune system function by stopping or slowing the growth and spread of cancer cells and help the immune system destroying cancer cells. Targeted therapies are either antibodies or drugs that work to inhibit specific proteins that are important for the growth and/or survival of cancer cells. Because targeted therapy agents do not directly interfere with rapidly dividing cells, they do not have the usual side effects of conventional chemotherapy (although they do have their own side effects) [58]. The major concern is the exorbitantly high costs of these immuno- and targeted therapies and that they are often prescribed for patients with an end-stage disease.

Back in 2006 the Dutch Council for Healthcare and Society proclaimed that the costs of an intervention per quality-adjusted life year should not exceed €80,000 [59]. Therefore questions rise whether innovative therapies undermine the development of a sustainable healthcare. For example, in 2012 Ipilimumab, an anti-CTLA4 antibody, came available in the Netherlands and initially it could be used as a second line treatment for patients with unresectable or metastatic melanoma. It is administered in a dosage of 3mg/kg and repeated three times (four treatments in total, regardless of the appearance of new lesions or growth of existing lesions) [60]. Costs of 50mg Ipilimumab are €4,505. For a 60kg patient this means that total costs for four treatments exceed €60,000 [61]. For metastatic colorectal cancer, Ramucirumab (an antibody targeting the VEGF receptor 2) can be added to chemotherapy (FOLFIRI) when there is still progression of the disease after failure of other targeted therapies (like Bevacizumab, Oxaliplatine and Fuoropyrimidine). For a patient of 60 kilograms, 480mg of Ramucirumab can be given every two weeks till progression of the disease or until unacceptable toxicity occurs [60]. Costs of 100mg Ramucirumab are €572.40, resulting in almost €5,500 on a monthly basis [61]. These striking high costs raise the question whether resources in healthcare are spend in the right manner and if these targeted therapies might even threat sustainability of healthcare in general.

In 2013 the Dutch Melanoma Treatment Registry was founded in order to track the performance of Ipilimumab and B-RAF inhibitors [62]. Perhaps for other targeted therapies, and also for new surgical and/or radio-therapeutic therapies (like stapler material, implants, robotic surgery or proton therapy), implementation of clinical audits can fulfill an important role by tracking their performances in 'real world' clinical practice. As a result, such audits might identify patient groups that do benefit most from these expensive therapies and patient groups that do not, leading to more appropriate care and a more sustainable healthcare system.

Improving clinical audits' value

Clinical audits traditionally cover clinical outcomes only and are most of the times focused on a single procedure or intervention[2,3,63], rather than covering the full cycle of care. For colorectal cancer surgery, covering the full cycle of care would imply that also outcomes of colorectal cancer screening programs and related diagnostic procedures should be incorporated, as well as tracking long-term clinical and/or financial outcomes (e.g. 5-year survival rates). In the Netherlands, this for example means that the Dutch Gastrointestinal Endoscopy Audit [64] should be merged with the Dutch Surgical Colorectal Audit [2] in order to cover both diagnostic and treatment processes.

The Dutch Parkinson's Insight Audit is a good example of a trans-mural audit: clinicians, paramedics and general physicians contribute in order to register and improve clinical outcomes and patient related outcome measures (PROMs) [65]. In 2015 the Dutch Society of Doctors for Lung Diseases and Tuberculosis, the Dutch Society for Radiotherapy and Oncology, the Dutch Association for Cardio-thoracic Surgeons and the Dutch Society for Lung Surgery have formed the Dutch Lung Cancer Audit [66]. This bundled audit covers the entire diagnostic and treatment program for all patients with lung cancer in the Netherlands. Currently it is further developed as a blue print for 'whole care cycle' audits in the Netherlands. Therefore, also the DSCA will be transformed in a patient-centered disease specific audit. After its multidisciplinary extension in 2017, this new audit will cover the full care cycle of colorectal cancer patients in the Netherlands (Dutch Colorectal Cancer Audit).

Doctors think about colorectal cancer surgery in terms of anastomotic leakage. The average patient does not. This is also shown in recent literature describing that

patient related outcome measures (PROMs) are not correlated with early preoperative events in bariatric surgery, therefore adding new information in treatment evaluation [67]. A systematic review showed that overall PROMs intervention effect sizes were small-to-moderate, however the routine use of PROMs might lead to improved symptom control and patient satisfaction, leading to more discussions of patient outcomes during consultation [68]. This is why future registries should incorporate PROMs in order to provide meaningful data for patients [69]. Although there are some initiatives pioneering integration of PROMs into daily practice [70], only a few have adopted it into nationwide programs [71].
In 2012, a joint taskforce of the Karolinska Institute in Sweden, Harvard Business School and the Boston Consulting group initiated the International Consortium of Health Outcomes Measurement (ICHOM). The mission of ICHOM is to develop a new paradigm focused on health outcomes by defining global standard sets of outcome measures. Their aim is to have published standard sets covering more than half of the global disease burden by 2017 [72]. To make sure that outcomes that really matter to patients are measured, all their datasets cover besides clinical outcomes, PROMs as well. The ICHOM colorectal cancer standard set was developed in close cooperation with the Dutch Institution for Clinical Auditing (DICA) and includes for example outcomes regarding depression, pain, sexual dysfunction and health-related quality of life through validated questionnaires [73]. DICA has started with synchronizing its datasets with the ICHOM standard sets with incorporation of PROMs, that are already available for several of its clinical audits.
Finally, embedding costs to an audit will tremendously increase the audit's value as shown in this thesis. The DVBHC-study was the first Dutch Institute of Clinical Auditng (DICA) database-based study to be linked in such manner. Performation [51] and DICA are now making steps to set up more (pilot) costs studies for other audits, like the Dutch Upper GI Cancer Audit (DUCA) and the Dutch Audit for Treatment of Obesity (DATO). Since accurate cost calculations are complex and should (nationwide) be performed in a uniformly manner, the question remains whether this is feasible. However, if healthcare providers can track down their expenses they can identify where their provided care is most costly and where it is not. This

might reveal the best opportunities for dedicated quality improvement programs leading to better outcomes for patients.

Implementation of undeveloped aspects of the 'value agenda'

Several aspects of the 'value agenda' have not been addressed in this thesis. To enable the full power of the value agenda, health care providers should also embrace the other components as suggested by Michael Porter [40].

For colorectal cancers we suggest the following items:

Organize into integrated practice units

Colorectal cancer surgeons might seek stronger collaboration with gastroenterologists, oncologist and radiotherapists and define their common goal: improving the outcomes for colorectal cancer patients. That means that, besides participation in weekly multidisciplinary meetings, each clinician should feel accountable for not only treating the disease, but also for treating the related complications and treating related circumstances that occur with it. For example, surgeons may choose to construct a diverting ileo-stoma (in order to protect the low anastomoses seen in rectal cancer [57]), however they should be aware of the stoma related complications. For example, non-surgical stoma related complications are most of the times seen by the stoma care nurse (e.g. failure of appropriate stoma handling, superficial wound infections) and/or the internal medicine doctor (e.g. dehydration). Sharing information on long-term complications might also provide valuable insights for radiotherapist, since they are often not involved during the follow-up period and therefore not noticing the long-term toxicity of radiotherapy. Also sharing wards and/or out-clinic departments between surgeons and for example gastroenterologists might lead to a more direct treatment plan with fewer in-hospital referrals. Shared accountability might enhance direct feedback (short-loop communication) and stimulate relevant discussions between providers. In other hospitals where integrated practice units have been introduced, like the Martini Klinik in Hamburg [74] and the Cleveland Clinic in Ohio[75], specialists are aligned around the care of a single diagnosis leading to more satisfaction for both patients and doctors.

Integrate care delivery across separate facilities

First colorectal cancer health care providers should define the scope of services for each hospital in a certain region. Community providers can usually work very effective, like shorter turnover times between surgeries or scheduling more out-clinic visits a day, and should ideally focus on less complex procedures/ proceedings. Academic centers have traditionally more heavily resourced facilities, therefore facilitating the infrastructure for more complex surgeries, like surgery for frail ASA III-IV patients. Second, care should be integrated across the different locations. For example, after a complex procedure is performed in an academic hospital, post-operative physiotherapy or stoma care can be performed closer to home. Important note is that the IPU still manages the full cycle of care and should for example be responsible for developing uniform protocols between the facilities. The Leiden University Medical Center is now teaming up with Haaglanden Medical Center (HMC), a major hospital in The Hague with multiple locations, in order to create the University Cancer Center Leiden|The Hague [76]. In the near future, surgeons of both institutions will perform surgeries in one of the HMC locations, which will entirely focus on treating cancer. In addition, complex colorectal cancer patients (e.g. ASA IV patients) of the greater Leiden – The Hague area will be redirected to the Leiden University Medical Center.

Build an enabling information technology platform

This component should powerfully enable all other components of the value agenda. Unfortunate information technology (IT) systems are lagging behind in most hospitals. In the greater Leiden area, almost all surrounding hospitals run on a different IT system, not even mentioning other health care providers like general practitioners or nursing facilities. Creating synergies between the different systems should catalyze efficient evaluation of treatments and optimize communication between different (located) health care providers. For example, treatment of colorectal cancer patients might improve when general physicians can easily reach out to specialist by leaving notes or pictures of wounds in the electronic patient record system in order to decide if a patient has to be redirected to the hospital again.

Also linking hospitals IT systems to audit IT systems (such as these of the DICA) could lead to easy accessible key information for healthcare providers on disease specific performances. Moreover, linking IT systems should enable data extraction for research and/ or audits. Since data extraction and verification for auditing is a time and cost consuming exercise [6,9] this certainly improve the usability of the audit. Although a lack of a perfect IT system is well recognized by most providers, there is no ideal IT system available in the market yet.

CONCLUSION

This thesis shows that quality of colorectal cancer care is irrevocably associated with hospital costs. Although surgical auditing is a cost and time-consuming exercise, it has a strong potential to improve outcomes in healthcare and simultaneously reduce hospital costs. Comparing hospital performances on both quality and costs makes identification of 'best practice' hospitals possible. Moreover, providing combined quality-cost outcomes of frail patients or operation techniques provides valuable insights where to start quality improvement initiatives. Finally, rewarding healthcare providers based on operative risk could be a first step in developing powerful reimbursement systems. This all might catalyze the continuous improvement of value leading to a more sustainable healthcare system in the future.

REFERENCES

1. Porter ME, Teisberg E. *Redefining healthcare: creating value based competition on results.*: Harvard Business Review Press; 2006.
2. Van Leersum NJ, Snijders HS, Henneman D, et al. The Dutch surgical colorectal audit. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2013;39(10):1063-1070.
3. Khuri SF, Daley J, Henderson W, et al. The Department of Veterans Affairs' NSQIP: the first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care. National VA Surgical Quality Improvement Program. *Annals of surgery.* 1998;228(4):491-507.
4. Govaert JA, van Bommel AC, van Dijk WA, van Leersum NJ, Tollenaar RA, Wouters MW. Reducing healthcare costs facilitated by surgical auditing: a systematic review. *World journal of surgery.* 2015;39(7):1672-1680.
5. Schilling PL, Dimick JB, Birkmeyer JD. Prioritizing quality improvement in general surgery. *Journal of the American College of Surgeons.* 2008;207(5):698-704.
6. Hammermeister K. The National Surgical Quality Improvement Program: learning from the past and moving to the future. *American journal of surgery.* 2009;198(5 Suppl):S69-73.
7. Govaert JA, van Dijk WA, Fiocco M, et al. Nationwide Outcomes Measurement in Colorectal Cancer Surgery: Improving Quality and Reducing Costs. *Journal of the American College of Surgeons.* 2016;222(1):19-29 e12.
8. Busweiler LA, Wijnhoven BP, van Berge Henegouwen MI, et al. Early outcomes from the Dutch Upper Gastrointestinal Cancer Audit. *The British journal of surgery.* 2016.
9. Govaert JA, Fiocco M, van Dijk WA, et al. Costs of complications after colorectal cancer surgery in the Netherlands: Building the business case for hospitals. *European journal of surgical oncology : the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology.* 2015;41(8):1059-1067.
10. Schwenk W, Haase O, Neudecker J, Muller JM. Short term benefits for laparoscopic colorectal resection. *Cochrane Database Syst Rev.* 2005(3):CD003145.
11. Kuhry E, Schwenk W, Gaupset R, Romild U, Bonjer J. Long-term outcome of laparoscopic surgery for colorectal cancer: a cochrane systematic review of randomised controlled trials. *Cancer Treat Rev.* 2008;34(6):498-504.
12. Kolfschoten NE, van Leersum NJ, Gooiker GA, et al. Successful and safe introduction of laparoscopic colorectal cancer surgery in Dutch hospitals. *Annals of surgery.* 2013;257(5):916-921.
13. Bartels SA, Vlug MS, Hollmann MW, et al. Small bowel obstruction, incisional hernia and survival after laparoscopic and open colonic resection (LAFA study). *The British journal of surgery.* 2014;101(9):1153-1159.
14. Stevenson AR, Solomon MJ, Lumley JW, et al. Effect of Laparoscopic-Assisted Resection vs Open Resection on Pathological Outcomes in Rectal Cancer: The ALaCaRT Randomized Clinical Trial. *Jama.* 2015;314(13):1356-1363.
15. Fleshman J, Branda M, Sargent DJ, et al. Effect of Laparoscopic-Assisted Resection vs Open Resection of Stage II or III Rectal Cancer on Pathologic Outcomes: The ACOSOG Z6051 Randomized Clinical Trial. *Jama.* 2015;314(13):1346-1355.

16. Braga M, Vignali A, Zuliani W, Frasson M, Di Serio C, Di Carlo V. Laparoscopic versus open colorectal surgery: cost-benefit analysis in a single-center randomized trial. *Annals of surgery.* 2005;242(6):890-895, discussion 895-896.
17. Dreyer NA, Garner S. Registries for robust evidence. *Jama.* 2009;302(7):790-791.
18. Buskens C. Clinical study designs and corresponding levels of evidence: time to redefine? *Colorectal disease : the official journal of the Association of Coloproctology of Great Britain and Ireland.* 2015;17(9):745-746.
19. Delaney CP, Chang E, Senagore AJ, Broder M. Clinical outcomes and resource utilization associated with laparoscopic and open colectomy using a large national database. *Annals of surgery.* 2008;247(5):819-824.
20. Govaert JA, Fiocco M, Dijk WAv, et al. Financiële uitkomsten na laparoscopie en laparotomie voor oncologische colorectale chirurgie: een multicenter population-based studie. The Dutch Association of Surgeons - annual meeting; 2015; Veldhoven, The Netherlands.
21. Gietelink L, Wouters MW, Bemelman WA, et al. Reduced 30-Day Mortality After Laparoscopic Colorectal Cancer Surgery: A Population Based Study From the Dutch Surgical Colorectal Audit (DSCA). *Annals of surgery.* 2016;264(1):135-140.
22. Govaert JA, Fiocco M, van Dijk WA, et al. Multicenter Stratified Comparison of Hospital Costs Between Laparoscopic and Open Colorectal Cancer Resections: Influence of Tumor Location and Operative Risk. *Annals of surgery.* 2016.
23. Govaert JA, van Dijk WA, Wouters WM. Gedifferentieerd belonen: een instrument naar verdere kwaliteitsverbetering en kostenreductie in de gezondheidszorg? *Nederlands tijdschrift voor geneeskunde.* 2017 (accepted).
24. Franks PJ, Bosanquet N, Thorpe H, et al. Short-term costs of conventional vs laparoscopic assisted surgery in patients with colorectal cancer (MRC CLASICC trial). *Br J Cancer.* 2006;95(1):6-12.
25. Jensen CC, Prasad LM, Abcarian H. Cost-effectiveness of laparoscopic vs open resection for colon and rectal cancer. *Diseases of the colon and rectum.* 2012;55(10):1017-1023.
26. DICA. *DSCA jaarrapportage 2015.* 2016.
27. van der Linden YT, Bosscha K, Prins HA, Lips DJ. Single-port laparoscopic cholecystectomy vs standard laparoscopic cholecystectomy: A non-randomized, age-matched single center trial. *World J Gastrointest Surg.* 2015;7(8):145-151.
28. van der Linden YT, Boersma D, van Poll D, Lips DJ, Prins HA. Single-port laparoscopic appendectomy in children: single center experience in 50 patients. *Acta chirurgica Belgica.* 2015;115(2):118-122.
29. van der Linden YT, Govaert JA, Fiocco M, van Dijk WA, Lips DJ, Prins HA. Single center cost analysis of single-port and conventional laparoscopic surgical treatment in colorectal malignant diseases. *International journal of colorectal disease.* 2016.
30. Alptekin H, Yilmaz H, Acar F, Kafali ME, Sahin M. Incisional hernia rate may increase after single-port cholecystectomy. *Journal of laparoendoscopic & advanced surgical techniques Part A.* 2012;22(8):731-737.
31. Govaert JA, Lijftogt N, van Dijk WA, et al. Colorectal cancer surgery for obese patients: Financial and clinical outcomes of a Dutch population-based registry. *Journal of surgical oncology.* 2016;113(5):489-495.
32. Tapper R, Dixon L, Frampton C, Frizelle F. Impact of obesity on the cost of major colorectal surgery. *The British journal of surgery.* 2013;100(2):293-298.

33. Wick EC, Hirose K, Shore AD, et al. Surgical site infections and cost in obese patients undergoing colorectal surgery. *Archives of surgery.* 2011;146(9):1068-1072.
34. Fransen E, Van Laer L, Lemkens N, et al. A novel Z-score-based method to analyze candidate genes for age-related hearing impairment. *Ear and hearing.* 2004;25(2):133-141.
35. OECD. Overweight or obese population (indicator). https://data.oecd.org/healthrisk/overweight-or-obese-population.htm. Accessed 08-04-2016.
36. Mullen JT, Moorman DW, Davenport DL. The obesity paradox: body mass index and outcomes in patients undergoing nonbariatric general surgery. *Annals of surgery.* 2009;250(1):166-172.
37. Govaert GA, van Helden S. Ty-raps in trauma: a novel closing technique of extremity fasciotomy wounds. *The Journal of trauma.* 2010;69(4):972-975.
38. Schermerhorn ML, O'Malley AJ, Jhaveri A, Cotterill P, Pomposelli F, Landon BE. Endovascular vs. open repair of abdominal aortic aneurysms in the Medicare population. *The New England journal of medicine.* 2008;358(5):464-474.
39. Govaert JA, Govaert MJ, Fiocco M, et al. Hospital costs of colorectal cancer surgery for the oldest old: A Dutch population-based study. *Journal of surgical oncology.* 2016.
40. Porter ME, Lee TH. The Strategy That Will Fix Health Care. *Harvard business review.* 2013;91(12):24-24.
41. Eappen S, Lane BH, Rosenberg B, et al. Relationship between occurrence of surgical complications and hospital finances. *Jama.* 2013;309(15):1599-1606.
42. Porter ME, Kaplan RS. How to pay for health care. *Harvard business review.* 2016;94(7/8).
43. Schippers EI. *Kamerbrief met reactie op artikel invoering van de uitkomstbekostiging per 2020.* 23-06-2015 2015.
44. Kaplan RS, Anderson SR. Time-driven activity-based costing. *Harvard business review.* 2004;82(11):131-138, 150.
45. Mercier G, Naro G. Costing hospital surgery services: the method matters. *PloS one.* 2014;9(5):e97290.
46. Guillamondegui OD, Gunter OL, Hines L, et al. Using the National Surgical Quality Improvement Program and the Tennessee Surgical Quality Collaborative to improve surgical outcomes. *Journal of the American College of Surgeons.* 2012;214(4):709-714; discussion 714-706.
47. Henke PK, Kubus J, Englesbe MJ, Harbaugh C, Campbell DA. A statewide consortium of surgical care: a longitudinal investigation of vascular operative procedures at 16 hospitals. *Surgery.* 2010;148(4):883-889; discussion 889-892.
48. Hollenbeak CS, Boltz MM, Wang L, et al. Cost-effectiveness of the National Surgical Quality Improvement Program. *Annals of surgery.* 2011;254(4):619-624.
49. Janson M, Bjorholt I, Carlsson P, et al. Randomized clinical trial of the costs of open and laparoscopic surgery for colonic cancer. *The British journal of surgery.* 2004;91(4):409-417.
50. Crawshaw BP, Chien HL, Augestad KM, Delaney CP. Effect of laparoscopic surgery on health care utilization and costs in patients who undergo colectomy. *JAMA surgery.* 2015;150(5):410-415.
51. Performation. http://www.performation.com.
52. *'De zorg: hoeveel extra is het ons waard?'.* The Dutch Ministry of Health Welfare and Sport; 2012-12-06 2012.

53. Zorgvisie. Meander MC laat verzekerden VGZ langer wachten. . 2016-07-21; https://www.zorgvisie.nl/financien/nieuws/2016/7/meander-mc-laat-verzekerden-vgz-langer-wachten/. Accessed 2016-09-25.
54. James BC, Poulsen GP. The Case for Capitation. *Harvard business review.* 2016;94(7/8).
55. Porter ME, Marks CM, Landman ZC. *OrthoChoice: Bundled Payments in the County of Stockholm.*: Harvard Business School;2014. 714515-PDF-ENG.
56. Munneke M, Nijkrake MJ, Keus SH, et al. Efficacy of community-based physiotherapy networks for patients with Parkinson's disease: a cluster-randomised trial. *The Lancet Neurology.* 2010;9(1):46-54.
57. Snijders HS, van Leersum NJ, Henneman D, et al. Optimal Treatment Strategy in Rectal Cancer Surgery: Should We Be Cowboys or Chickens? *Ann Surg Oncol.* 2015;22(11):3582-3589.
58. UpToDate. Colorectal cancer treatment; metastatic cancer - targeted therapies. http://www.uptodate.com. Accessed 2016-11-15.
59. *Zinnige en duurzame zorg.* Dutch Council for Healthcare and Society (RVS);2006.
60. ZorginstituutNederland. Farmacotherapeutisch Kompas. 2016; http://www.farmacotherapeutischkompas.nl. Accessed 2016-11-14.
61. ZorginstituutNederland. Medicijnkosten. 2016; http://www.medicijnkosten.nl. Accessed 2016-11-14.
62. DICA. Dutch Melanoma Treatment Registry. 2016; https://www.dica.nl/dmtr/home. Accessed 2016-11-14.
63. Lothian and Borders large bowel cancer project: immediate outcome after surgery. The consultant surgeons and pathologists of the Lothian and Borders Health Boards. *The British journal of surgery.* 1995;82(7):888-890.
64. DICA. Dutch Gastrointestinal Endoscopy Audit https://www.dica.nl/dgea/home. Accessed 2016-11-11.
65. DICA. Dutch Parkinson's Insight Audit. https://www.dica.nl/dpia/home. Accessed 2017-01-22.
66. DICA. Dutch Lung Cancer Audit. https://www.dica.nl/dlca/home. Accessed 2016-11-11.
67. Waljee JF, Ghaferi A, Cassidy R, et al. Are Patient-reported Outcomes Correlated With Clinical Outcomes After Surgery?: A Population-based Study. *Annals of surgery.* 2016;264(4):682-689.
68. Kotronoulas G, Kearney N, Maguire R, et al. What is the value of the routine use of patient-reported outcome measures toward improvement of patient outcomes, processes of care, and health service outcomes in cancer care? A systematic review of controlled trials. *J Clin Oncol.* 2014;32(14):1480-1501.
69. Luckett T, Butow PN, King MT. Improving patient outcomes through the routine use of patient-reported data in cancer clinics: future directions. *Psychooncology.* 2009;18(11):1129-1138.
70. Ashley L, Jones H, Thomas J, et al. Integrating patient reported outcomes with clinical cancer registry data: a feasibility study of the electronic Patient-Reported Outcomes From Cancer Survivors (ePOCS) system. *J Med Internet Res.* 2013;15(10):e230.
71. Rolfson O, Karrholm J, Dahlberg LE, Garellick G. Patient-reported outcomes in the Swedish Hip Arthroplasty Register: results of a nationwide prospective observational study. *The Journal of bone and joint surgery British volume.* 2011;93(7):867-875.

72. International Consortium of Health Outcomes Measurement (ICHOM). http://www.ichom.org. Accessed 2016-11-15.

73. ICHOM Standard Set for Colorectal cancer. http://www.ichom.org/medical-conditions/colorectal-cancer/. Accessed 2016-11-15.

74. Martini Kliniek. http://www.martini-klinik.de. Accessed 2016-11-15.

75. Cleveland Clinic. http://my.clevelandclinic.org. Accessed 2016-11-15.

76. LUMC en MCH-Bronovo starten het Universitair Kankercentrum Leiden | Den Haag. *Intranet Leiden University Medical Center*2016.

CHAPTER 11

NEDERLANDSE SAMENVATTING

Nederland staat qua gezondheid systeem sinds 2008 onafgebroken op nummer één in de European Health Consumer Index, een index gericht op het vergelijken van Europese gezondheidszorg systemen. De keerzijde van de medaille is dat het Nederlandse systeem ook wordt gezien als één van de duurste in Europa. Ontwikkelingen omtrent beschikbaarheid van innovatieve geneesmiddelen en vergrijzing van de Nederlandse bevolking zullen de doelmatigheid van onze zorg nog verder op de proef stellen. Om te bepalen waar en/of welke zorg doelmatig wordt uitgevoerd is het bijhouden en analyseren van betrouwbare sturingsinformatie essentieel.

De Dutch Institute for Clinical Auditing (DICA) is opgericht met als doel kwaliteit van zorg transparant te maken, te vergelijken en te verbeteren, door middel van metingen en analyses. In 2009 startte de eerste registratie gericht op patiënten die werden geopereerd aan een colorectaal carcinoom, de Dutch Surgical Colorectal Audit (DSCA). In de eerste jaren na implementatie van deze registratie werd duidelijk dat landelijke richtlijnen omtrent colorectale ingrepen beter werden nageleefd en dat postoperatieve complicaties en mortaliteit daalden. Om de financiële gevolgen hiervan te analyseren werd de Dutch Value Based Healthcare study (DVBHC-study) gestart. Voor deze studie zijn van 29 Nederlandse ziekenhuizen de DSCA gegevens tussen 2010 en 2012 gekoppeld aan een financiële database. Deze database bevat de kostprijzen en alle verrichtingen die per patiënt zijn uitgevoerd vanaf de opname tot 90 dagen na ontslag. Doordat de kostprijzen op een uniforme manier in alle deelnemende ziekenhuizen zijn gemeten is een vergelijking tussen ziekenhuizen en patiënten goed uitvoerbaar. Data van de DVBHC-study is gebruikt voor hoofdstukken **3, 4, 5, 7, 8 en 9** van dit proefschrift.

Chirurgische audits en ziekenhuiskosten

Hoofdstuk 2 van dit proefschrift beschrijft de resultaten van de literatuur studie (systematic review) waarbij gekeken is naar de relatie tussen chirurgische registraties en kostenbesparing. Ondanks dat deze relatie vaak wordt aangenomen, waren van de meer dan 3.600 onderzochte artikelen slechts zes die deze relatie daadwerkelijk beschreven. Alle zes de artikelen beschreven een positief effect waarbij het

registreren en terugkoppelen van klinische uitkomsten leidt tot het verminderen van complicaties en een reductie in kosten.
De conclusies van de literatuur studie werden bevestigd door de uitkomsten van de DVBHC-studie. **Hoofdstuk 3** laat namelijk zien dat in drie jaar tijd (2010-2012) de klinische uitkomsten in de deelnemende ziekenhuizen verbeterden (reductie van 20% in mortaliteit en 29% in gecompliceerd beloop) en dat de kosten in dezelfde periode met 9% afnamen (van 14.237 euro per patiënt naar 13.145 euro per patiënt). Ziekenhuizen die het percentage ernstige postoperatieve complicaties niet konden verminderen (n=7) waren in deze periode 390 euro per patiënt duurder uit. Ziekenhuizen die het percentage ernstige complicaties zagen afnemen met 0-10% (n=12) of meer dan 10% (n=10) waren respectievelijk 1.353 euro en 2.158 euro per patiënt goedkoper uit. Wanneer alle deelnemende ziekenhuizen zouden presteren als de 'best practice groep' zou er in drie jaar tijd meer dan 20 miljoen euro zijn bespaard. Deze potentiele besparing is gebaseerd op alleen het chirurgische gedeelte van de behandeling van het colorectaal carcinoom, mogelijk is de totale potentiele kostenbesparing nog hoger.
Aangezien registratie en verificatie van de klinische uitkomsten een dure en tijdrovende bezigheid is, geeft **hoofdstuk 4** de business case weer. Hierin wordt aangetoond dat, ondanks de tijd en de kosten die gepaard gaan met de registratie voor de DSCA, deelname resulteert in een kostenbesparing van 80.393 euro per ziekenhuis in drie jaar tijd (voor een ziekenhuis met een gemiddelde van 100 colorectale resecties). Bovendien gaat dit hoofdstuk in op de enorme financiële impact van ernstige complicaties: de 5% duurste patiënten waren verantwoordelijk voor 23% van de totale kosten. Daarnaast bedroegen de additionele kosten van patiënten met complicaties 30% van het totale budget.

Chirurgische technieken en ziekenhuiskosten

In de laatste twee decennia heeft laparoscopie zich bewezen als een algemeen geaccepteerde chirurgische techniek voor de behandeling van het colorectaal carcinoom. Recente literatuur laat zien dat laparoscopie gepaard gaat met sneller postoperatief herstel en overeenkomstige (lange termijn) oncologische resultaten in vergelijking tot open chirurgie. Verrassend genoeg is het kostenverschil tussen deze twee technieken minder vaak en minder goed onderzocht. Meestal zijn kostenstudies naar deze twee operatietechnieken verricht als onderdeel van een gerandomiseerde klinische studie met een andere primaire onderzoeksvraag. Bovendien gaat het vaak om geselecteerde patiëntengroepen bestaande uit patienten die meestal geopereerd zijn door een gespecialiseerd team. Dit maakt dat de resultaten moeilijk te extrapoleren zijn naar andere ziekenhuizen. Bovendien is onderzoek naar zorgkosten op nationaal niveau uitdagend omdat uniformiteit (en transparantie) van kostprijsberekening tussen verschillende ziekenhuizen vaak ontbreekt.

In **hoofdstuk 5** zijn de kosten voor electieve chirurgie van niet op afstand gemetastaseerde patiënten met een colorectaal carcinoom beschreven (tumor stadium T1-3N0-2M0). Om inzicht te krijgen in verschillen tussen de risicogroepen werd naast stratificatie voor operatietechniek (open versus laparoscopisch) ook gekeken naar tumorlocatie (colon versus rectum), leeftijd (<75jaar versus ≥75jaar) en ASA classificatie (ASA I-II versus ASA III-IV). Verschil in ziekenhuiskosten tussen de subgroepen varieerde van €10.474 tot €20.865 afhankelijk van het risico profiel van de groep. Daarnaast was een laparoscopische operatie goedkoper dan de open chirurgische techniek bij patiënten met een coloncarcinoom. Dit is te verklaren door minder complicaties en kortere opnameduur in de laparoscopisch geopereerde patiëntengroepen. Laparoscopische ingrepen bij rectum chirurgie resulteerden juist in hogere kosten dan de open chirurgische techniek. Een mogelijke verklaring hiervoor is dat bij rectumchirurgie in ongeveer 80% van de gevallen een stoma werd aangelegd. Waarschijnlijk interfereert het aanleggen van een stoma met de voordelen die worden gezien bij laparoscopische colon chirurgie, zoals een kortere opnameduur.

Tegenwoordig wordt 70% van de coloncarcinoom resecties en 85% van de rectumcarcinoom resecties laparoscopisch uitgevoerd. Een relatief nieuwe laparoscopische techniek is de ‘single port laparoscopy’ (SPL), waarbij de gehele procedure via één incisie wordt uitgevoerd. Aangezien er weinig bekend is over de kosten van het gebruik van SPL is in **hoofdstuk 6** een kostenanalyse beschreven voor SPL en de conventionele laparoscopische procedures die tussen 2011 en 2012 werden uitgevoerd in het Jeroen Bosch Ziekenhuis in ’s-Hertogenbosch. De kosten per patiënt van SPL waren over de twee geanalyseerde jaren hoger dan die van conventionele laparoscopie. Echter, in het tweede jaar daalden de kosten van SPL, waarmee de kosten vergelijkbaar werden met die van de conventionele laparoscopie. Tot slot werden er geen significante verschillen gezien betreffende de klinische uitkomsten tussen beide groepen. De resultaten in dit hoofdstuk waren gebaseerd op een relatieve kleine groep (78 SPL en 189 conventionele laparoscopische procedures) en moeten daarom dienen als een stimulans voor nader onderzoek.

Hoog-risico patiënten en ziekenhuiskosten

Het opereren van hoog-risico patiënten gaat vaak gepaard met hoge ziekenhuis-kosten. In **hoofdstuk 7** en **hoofdstuk 8** wordt de financiële impact van de twee veel voorkomende risicofactoren op een gecompliceerd postoperatief beloop geanalyseerd.

Hoofdstuk 7 beschrijft de impact van obesitas op ziekenhuis kosten van geopereerde patiënten met een colorectaal carcinoom. Patiënten met een Body Mass Index (BMI) 35 kg/m^2 en hoger zijn geassocieerd met significant hogere ziekenhuis kosten, tot wel 22 procent, ten opzichte van patiënten met een normaal gewicht. Aangezien in de toekomst steeds meer patiënten aan obesitas zullen lijden, betekent dit dat de kosten voor behandeling van colorectale carcinoom patiënten ook steeds meer zullen toenemen. Daarnaast beschrijft dit hoofdstuk voor het eerst een beschermend effect van pre-obesitas op mortaliteit binnen de colorectale chirurgie. Dit wordt de ‘obesitas-paradox’ genoemd waarbij patiënten met een BMI tussen de 25 kg/m^2 en 30 kg/m^2 een lager risico op overlijden hebben dan patiënten met een BMI $\leq$ 25 kg/m^2.

Hoofdstuk 8 beschrijft dat de behandeling van de oudste patiëntengroep (85 jaar en ouder) met een colorectaal carcinoom geassocieerd is met een hogere morbiditeit en mortaliteit. Echter, de behandeling van deze groep patiënten is niet geassocieerd met een stijging in ziekenhuiskosten. Dit is te verklaren doordat er voor de oudste patiënten minder middelen werden verbruikt bij het behandelen van complicaties (bijvoorbeeld minder ICU ligdagen en kortere re-operatietijden). Bovendien bleek er sprake te zijn van een hogere mortaliteit na het optreden van complicaties ('failure to rescue') in vergelijking met patiënten jonger dan 85 jaar. Een duidelijke verklaring hiervoor is niet uit de DSCA database te halen, maar meest waarschijnlijk komt dit doordat de oudste patiënten een beperkte fysieke reserve hebben waardoor ze bij complicaties sneller komen te overlijden. Een andere verklaring is dat bij deze patiëntengroep vaak gekozen wordt voor een minder agressieve behandeling in het geval van complicaties. Omdat de DSCA de dagelijkse praktijk reflecteert geven deze conclusies aan dat op korte termijn financiële argumenten niet van belang zijn voor de chirurgische behandeling van oudere patiënten met colorectaal carcinoom.

Declaraties en kwaliteitsverbetering

Het huidige Nederlandse declaratiesysteem draagt niet bij aan verbetering van kwaliteit van zorg voor de patiënt met een colorectaal carcinoom. Zo wordt bijvoorbeeld de beloning voor colorectale chirurgische zorg met name bepaald door de ligduur van patiënten (langer of korter dan 28 dagen opname) en niet op basis van geleverde uitkomsten.

Naar aanleiding van de grote verschillen in kosten tussen verschillende risico groepen (**hoofdstuk** 5) worden in **hoofdstuk 9** twee belangrijke tekortkomingen van dit systeem toegelicht. De eerste tekortkoming is dat het huidige systeem geen onderscheid maakt tussen hoog dan wel laag risico subgroepen. Hierdoor zijn er ziekenhuizen die goedkoper zijn, omdat ze voornamelijk (of uitsluitend) laag complexe patiënten behandelen. Daarnaast zijn de ziekenhuizen die zich focussen op complexe patiënten en/of complexe ingrepen duurder uit. Dit verschil wordt onder andere veroorzaakt door de zogenaamde volumenormen voor bijvoorbeeld de rectum chirurgie. Op zichzelf geen slechte ontwikkeling, alleen de beloning is hier momenteel niet op afgestemd. De tweede tekortkoming bestaat uit het feit dat het huidige systeem ingaat tegen het belonen van kwaliteit. Dit komt doordat het huidige systeem perverse prikkels bevat. Immers, op basis van de '28 dagen regel' kunnen gecompliceerde patiënten een 200% hoger bedrag opleveren indien ze langer dan 28 dagen opgenomen blijven. Daarnaast mag 42 dagen na ontslag een nieuw financieel product worden geopend, hetgeen korte termijn denken in de hand zou kunnen spelen.

Een volgende stap naar verdere kwaliteitsverbetering in de gezondheidszorg zou het belonen op basis van kwaliteit zijn. Aangezien dit niet met een 'big bang' dient te gebeuren stellen wij in **hoofdstuk 9** als eerste stap het gedifferentieerd belonen voor. Hierbij zal dan onderscheid moeten worden gemaakt tussen de verschillende risico profielen van patiënten. Zo kan de winstmarge van het ziekenhuis bepaald worden door het leveren van superieure kwaliteit, ongeacht de zorgzwaarte van de patiënt, hetgeen ziekenhuizen direct stimuleert tot het behalen van hoogwaardige uitkomsten. Bovendien zou de eerste stap naar gedifferentieerd belonen eenvoudig gemaakt kunnen worden omdat de huidige klinische registraties de benodigde patiëntkarakteristieken kunnen aanleveren voor risico profilering. Tot slot kan de klinische registratie bijdragen aan het uiteindelijke doel: belonen op basis van geleverde kwaliteit.

CONCLUSIE

Dit proefschrift laat zien dat kosten van medische zorg onherroepelijk verbonden zijn aan behaalde uitkomsten. Waar ziekenhuizen zich focussen op kwaliteit worden kosten bespaard. Daarnaast ondersteund dit proefschrift dat het gekoppeld rapporteren van klinische en financiële uitkomsten krachtige informatie geeft voor het starten van initiatieven om de kwaliteit te verbeteren. Het maakt inzichtelijk waar en op welke manier zorg het beste kan worden geleverd. Een logisch gevolg is dat ook overheid en zorgverzekeraar over gaan tot het belonen van behaalde uitkomsten hetgeen als een katalysator voor verder kwaliteitsverbetering zou moeten werken.

APPENDICES

LIST OF PUBLICATIONS

CURRICULUM VITAE

DANKWOORD

LIST OF PUBLICATIONS

From this thesis

1. Outcome-based reimbursement: a tool for further quality improvement in healthcare. **Govaert JA**, van Dijk WA, Wouters MWJM. Ned Tijdschr Geneeskd. 2017 Accepted.

2. Single center cost analyses of single-port and conventional laparoscopic surgical treatment in colorectal malignant diseases. Van der Linden Y*, **Govaert JA***, Fiocco M, van Dijk WA, Lips DJ, Prins HA. Int J Colorectal Dis. 2016 Oct 27. [Epub ahead of print]

3. Hospital costs of colorectal cancer surgery for the oldest old: a Dutch population based study. **Govaert JA**, Govaert MJPM, Fiocco M, van Dijk WA, Tollenaar RAEM, Wouters MWJM. J Surg Oncol. J Surg Oncol. 2016 Dec;114(8):1009-1015.

4. Multicenter stratified comparison of hospital costs between laparoscopic and open colorectal cancer resections; influence of tumor location and operative risk. **Govaert JA,** Fiocco M, van Dijk WA, Kolfschoten NE, Prins HA, Dekker JWT, Tanis PJ, Tollenaar RAEM and Wouters MWJM. Ann Surg. 2016 Sep 8. [Epub ahead of print]

5. Colorectal cancer surgery for obese patients: Financiel and clinical outcomes of a Dutch population-based registry. **Govaert JA,** Lijftogt N, van Dijk WA, Tseng L, Tollenaar RAEM, Fiocco M and Wouters MWJM. J Surg Oncol. 2016 Apr;113(5):489-95.

6. Nationwide outcome-measurement in colorectal cancer surgery: improving quality and reducing costs. **Govaert JA**, van Dijk WA, Fiocco M, Scheffer AC, Gietelink L, Wouters MWJM, Tollenaar RAEM. J Am Coll Surg. 2016 Jan;222(1):19-29.e2.

7. Costs of complications after colorectal cancer surgery in the Netherlands: building the business case. **Govaert JA**, Fiocco M, van Dijk WA, Scheffer AC, de Graaf EJR, Tollenaar RAEM, Wouters MWJM. Eur J Surg Oncol. 2015 Aug;41(8):1059-67.

8. Reducing healthcare costs facilitated by surgical auditing: a Systematic Review. **Govaert JA***, van Bommel ACM*, van Dijk WA, van Leersum N, Tollenaar RAEM, Wouters MWJM. World J Surg. 2015 Jul;39(7):1672-80.

Other publications by the author

9. Hospital costs of complications after esophagectomy for cancer. Groense L, van Dijk WA, **Govaert JA**, van Rossum PSN, Ruurda JP, van Hillegersberg R. Eur J Surg Oncol. 2016 Dec 5. doi: 10.1016/j.ejso.2016.11.013. [Epub ahead of print]

10. Simultaneous presentation of necrotizing soft tissue infection in the orbital area and the hand. Paridaans MP, **Govaert JA**, Scholten HH, de Lange DH. Ned Tijdschr Geneeskd. 2016;160(0):A9944.

11. A female patient with an unusual swelling in the groin. Dekkers S, **Govaert JA**, Baeten CI. Ned Tijdschr Geneeskd. 2015;159:A9079.

12. Timing of bone marrow cell delivery has minimal effects on cell viability and cardiac recovery after myocardial infarction. Swijnenburg RJ, **Govaert JA**, van der Bogt KE, Pearl JI, Huang M, Stein W, Hoyt G, Vogel H, Contag CH, Robbins RC, Wu JC. Circ Cardiovasc Imaging. 2010 Jan;3(1):77-85.

13. Poor functional recovery after transplantation of diabetic bone marrow stem cells in ischemic myocardium. **Govaert JA**, Swijnenburg RJ, Schrepfer S, Xie X, van der Bogt KE, Hoyt G, Stein W, Ransohoff KJ, Robbins RC, Wu JC. J Heart Lung Transplant. 2009 Nov;28(11):1158-1165.e1.

14. Comparison of transplantation of adipose tissue- and bone marrow-derived mesenchymal stem cells in the infarcted heart. van der Bogt KE, Schrepfer S, Yu J, Sheikh AY, Hoyt G, **Govaert JA**, Velotta JB, Contag CH, Robbins RC, Wu JC. Transplantation. 2009 Mar 15;87(5):642-52.

15. Immunosuppressive therapy mitigates immunological rejection of human embryonic stem cell xenografts. Swijnenburg RJ, Schrepfer S, **Govaert JA**, Cao F, Ransohoff K, Sheikh AY, Haddad M, Connolly AJ, Davis MM, Robbins RC, Wu JC. Proc Natl Acad Sci U S A. 2008 Sep 2;105(35):12991-6.

16. Novel immunosuppression: R348, a JAK3- and Syk-inhibitor attenuates acute cardiac allograft rejection. Deuse T, Velotta JB, Hoyt G, **Govaert JA**, Taylor V, Masuda E, Herlaar E, Park G, Carroll D, Pelletier MP, Robbins RC, Schrepfer S. Transplantation. 2008 Mar 27;85(6):885-92.

* Shared first author

CURRICULUM VITAE

Johannes Govaert was born in Waalwijk on August 15 1983 as youngest in a family of six children. Together with his twin-brother Klaas he graduated from the Dongemond College (Atheneum) in Raamsdonksveer in 2001 followed by a gap year in which they travelled through Australia and New Zealand.

In 2002 he started his study Medicine at Leiden University. During his study he worked as an assistant at the Thoracic Surgery Department at Leiden University Medical Center. He also was a volunteer for the Mara Foundation (medical transports to the Balkan area) and developed his organizations skills by participating in several committees at the student association Minerva. Between 2006 and 2007, with financial support of the Dutch Heart Foundation and the American Heart Association, he undertook his graduate research project 'Poor Functional Recovery After Transplantation of Diabetic Bone Marrow Stem Cells in Ischemic Myocardium' at the cardiovascular institute of Stanford University (Palo Alto, USA). This work was done under supervision of Professor Dr. Jaap Hamming (department of Vascular Surgery at the Leiden University Medical Center), Dr. Joseph Wu (departments of Cardiology & Radiology at Stanford University) and Professor Dr. Robert Robbins (department of Cardiothoracic Surgery at Stanford University). In 2007 Johannes started with his clinical rotations. During these two years he was a volunteer for the Atelier Foundation (organizing activities for underprivileged children in Amsterdam East). Before receiving his medical degree in 2010 Johannes performed a strategic consultancy internship at McKinsey & Company (Amsterdam) for a period of 15 weeks.

In 2010 Johannes worked for one year as a surgical resident at Onze Lieve Vrouwe Gasthuis (Amsterdam) under the supervision of Dr. Michael Gerhards. One year later he started his surgical training at the Groene Hart Ziekenhuis (Gouda) under the supervision of Dr. Roderick Schmitz. During this training he participated in different committees of the Groene Hart Ziekenhuis, including being chair of the Groene Hart Ziekenhuis residents association. Stimulated by the surgeons of the Groene Hart Ziekenhuis in 2013, he got the opportunity to become part of the research team at Leiden University Medical Center and the Dutch Institute for Clinical Auditing. For twelve months Johannes suspended his surgical training and dedicated his time focused on clinical and financial outcomes of colorectal cancer surgery under the supervision of Professor Dr. Rob Tollenaar, Dr. Michel Wouters and Dr. Marta Fiocco. The research project was the basis of this PhD thesis. In 2014 he returned to the Groene Hart Ziekenhuis in Gouda to continue his surgical training. In January 2015 he participated in the Value-Based Health Care Delivery Intensive Seminar of Professor Michael Porter (Harvard Business School, Boston, USA). The same year he volunteered for the Boat Refugee Foundation at Lesbos (Greece), providing first aid to boat refugees crossing the Aegean Sea from Turkey to Greece.

Johannes started in 2016 the academic part of his surgical training at Leiden University Medical Center in the field of surgical oncology under the supervision of Professor Dr. Jaap Hamming and Dr. Bert Bonsing. During the last three years of his surgical training Johannes was also the permanent resident representative of the regional surgical education committee (ROC) in region III.

Johannes Govaert lives together with his fiancée Carla Theunissen in Utrecht. He will defend his PhD thesis on the same day as his twin brother Klaas, who is a surgical resident as well and will be defending his thesis on colorectal liver metastasis at the University of Utrecht.

DANK!


CARLA
MIJN OUDERS
GEERTJE
WOUTER
KLAAS
ANDRIES
SOFIE
ANNA
MICHEL WOUTERS
ROB TOLLENAAR
MARTA FIOCCO
CO-AUTEURS
STEVEN LUGARD
HOLGER WAGENAAR
THEA KUIJPERS
PIETER TANIS
CHIRURGEN VBHC-STUDY
DICK
CHARLOTTE
AIOS LUMC
ANIOS LUMC
AIOS GHZ
ANIOS GHZ
MEDEWERKERS X-IS
MEDEWERKERS MRDM
MEDEWERKERS PERFORMATION
MAATSCHAP HEELKUNDE GHZ
OOM WILBERT
RODERICK SCHMITZ
ZIEKENHUIZEN VBHC-STUDY
DICA COLLEGA'S
C11-ONDERZOEKERS
WILLEMIEN EN ERIC
JAAP HAMMING
WIM SMIT
KATJA EN STEEF
RIM
REYER OTTOW
MARJOLIJN
ALEXANDER SCHREPFER
STANFORD BOYS (FOR BASIC SCIENCE): KOEN, RJ EN JAN STOOT