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Achievements in colorectal cancer care during 8 years of auditing in The Netherlands

Michael P.M. de Neree tot Babberich ^{a, b, *}, Robin Detering ^b, Jan Willem T. Dekker ^c,
Marloes A. Elferink ^d, Rob A.E.M. Tollenaar ^e, Michel W.J.M. Wouters ^f, Pieter J. Tanis ^b,
Dutch ColoRectal Audit Group

^a Department of Gastroenterology and Hepatology, Academic Medical Centre, University of Amsterdam, Amsterdam, The Netherlands

^b Department of Surgery, Academic Medical Centre, University of Amsterdam, Amsterdam, The Netherlands

^c Department of Surgery, Reinier de Graaf Hospital, Delft, The Netherlands

^d Department of Research, Netherlands Comprehensive Cancer Organization (IKNL), Utrecht, The Netherlands

^e Department of Surgery, Leiden University Medical Centre, Leiden, The Netherlands

^f Department of Surgical Oncology, Netherlands Cancer Institute-Antoni van Leeuwenhoek, Amsterdam, The Netherlands

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ABSTRACT

Introduction: The efficacy of auditing is still a subject of debate and concerns exist whether auditing promotes risk averse behaviour of physicians. This study evaluates the achievements made in colorectal cancer surgery since the start of a national clinical audit and assesses potential signs of risk averse behaviour.

Methods: Data were extracted from the Dutch ColoRectal Audit (2009–2016). Trends in outcomes were evaluated by uni and multivariable analyses. Patients were stratified according to operative risks and changes in outcomes were expressed as absolute (ARR) and relative risk reduction (RRR). To assess signs of risk averse behaviour, trends in stoma construction in rectal cancer were analysed.

Results: Postoperative mortality decreased from 3.4% to 1.8% in colon cancer and from 2.3% to 1% in rectal cancer. Surgical and non-surgical complications increased, but with less reintervention. For colon cancer, the high-risk elderly patients had the largest ARR for complicated postoperative course (6.4%) and mortality (5.9%). The proportion of patients receiving a diverting stoma or end colostomy after a (L)AR decreased 11% and 7%, respectively. In low rectal cancer, patients increasingly received a non-diverted primary anastomosis (5.4% in 2011 and 14.4% in 2016).

Conclusions: No signs of risk averse behaviour was found since the start of the audit. Especially the high-risk elderly patients seem to have benefitted from improvements made in colon cancer treatment in the past 8 years. For rectal cancer, trends towards the construction of more primary anastomoses are seen. Future quality improvement measures should focus on reducing surgical and non-surgical complications.

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Introduction

Clinical auditing is increasingly considered as an important tool for quality assessment and improvement [1–6]. In an audit, baseline risk adjusted and benchmarked feedback information on performance is provided to professionals, thereby facilitating improvement cycles [7–9]. Additionally, auditing can also be used to evaluate guideline implementation and to monitor new treatments. This is illustrated by one of the first audits in rectal cancer that evaluated the implementation of Total Mesorectal Excision for rectal cancer [10].

* Corresponding author. Academic Medical Center, Department of Gastroenterology and Hepatology, Meibergdreef 9, C2-317, 1105 AZ, Amsterdam, The Netherlands.

E-mail addresses: m.p.deneree@amc.uva.nl (M.P.M. de Neree tot Babberich), r.detering@amc.uva.nl (R. Detering), j.w.t.dekker@rdgg.nl (J.W.T. Dekker), M.Elferink@iknl.nl (M.A. Elferink), R.A.E.M.Tollenaar@lumc.nl (R.A.E.M. Tollenaar), m.wouters@nki.nl (M.W.J.M. Wouters), p.j.tanis@amc.uva.nl (P.J. Tanis).

However, the effectiveness of audits is still a subject of debate. A Cochrane review published in 2012 reported a positive but small effect of auditing on healthcare outcomes [11]. However, the magnitude of improvements varied strongly between studies. Although auditing can lead to overall improvements in outcomes over time, a still largely unresolved question is whether clinically relevant subgroups equally benefit from the advances made in colorectal cancer (CRC) treatment. Furthermore, critics have argued that improvements might also be related to patient selection by excluding high risk patients from surgery as a result of auditing, a phenomenon called risk aversion. Another example of risk averse behaviour could be avoiding the risks related to anastomotic leakage by performing more end-colostomies instead of low anastomoses.

Therefore, the purpose of this population-based analysis was to study outcomes of CRC treatment for different risk-stratified subgroups of patients since the start of the Dutch ColoRectal Audit (DCRA). In addition, potential risk averse behaviour was evaluated by determining proportions of surgically treated CRC patients over time based on the Netherlands Cancer Registry (NCR) and by analysing time trends of the proportion constructed colostomies in surgically treated (low) rectal cancer patients.

Materials and methods

Data were extracted from the DCRA, formerly known as the Dutch Surgical Colorectal Audit (DSCA). This audit collects information on patient, tumour, treatment and short-term outcome characteristics of all patients undergoing a resection for primary CRC in the Netherlands [12]. Every year, each hospital makes several structure, process and outcomes measures transparent on a hospital level to health care payers.

To enable a comprehensive view of CRC treatment over time and possible patient selection as a sign of risk averse behaviour, another independent source of data on both surgically and non-surgically treated CRC patients in the Netherlands was consulted: the NCR. The NCR uses the digital pathology archive (PALGA) and the National Registry of Hospital Discharge Diagnoses to notify of a newly diagnosed CRC [13].

Patients

For this study, no ethical approval or informed consent was required under Dutch law. All patients ($n = 78,866$) undergoing a surgical resection and registered in the DCRA between January 1st, 2009 and December 31st, 2016, were evaluated. Minimal data requirements were information on tumour location, date of surgery and 30-day/in-hospital mortality ($n = 78,416$). For the purpose of this study, it was decided to include only planned (elective) surgical resections and excluding multiple synchronous colorectal tumours [14]. Patients diagnosed through the CRC screening programme, which started in 2014, were also excluded. The screening population was considered a different (more favourable) CRC population that might influence on the studied outcomes over time, making interpretation of auditing effects more difficult [15,16]. This resulted in a total eligible number of 59,857 patients.

Data extraction and outcome parameters

The following data were extracted from the DCRA: patient and disease characteristics, procedural characteristics and post-operative outcome within 30 days after resection or in-hospital events. To evaluate overall trends in treatment for CRC, data on type of treatment for all registered CRC patients were extracted from the NCR. Type of treatment in the NCR was categorized as;

resection - elective, resection - non-elective, local excision, polypectomy, (chemo)radiotherapy (no resection), systemic therapy, radiotherapy and systemic therapy, only metastasectomy and/or radiotherapy for metastasis, no treatment, resection for other indication (incidental finding), treatment unknown.

Outcome parameters consisted of complicated postoperative course (post-operative complication resulting in a hospital stay >14 days and/or reintervention and/or postoperative mortality), in-hospital or 30-day mortality, surgical complication, non-surgical complication, reintervention (surgical, endoscopic or radiologic), postoperative length of stay (LOS), and readmission.

Data analysis

Analyses were performed separately for colon and rectal cancer. The first two years (2009–2010) were excluded from trend analyses, because different variables of interest, such as type of complication or reinterventions, were not yet registered and because of not-registered eligible patients in the DCRA of >5% compared with the NCR [12]. For 2009–2010, patient and tumour characteristics were only provided for informative purposes. To evaluate changes over time, data from the years 2011–2012 were compared to 2015–2016 and tested for statistical significance with a non-parametric Mann Whitney *U* test for non-normally distributed continuous variables (e.g. LOS, with a Bonferroni correction for multiple testing) or χ^2 -test for categorical variables.

To evaluate differences in outcomes, uni and multivariable logistic regression analysis was used. The following factors were included in the multivariable analysis to adjust for differences in risks; sex, age, American Society of Anesthesiologists (ASA) score, Charlson comorbidity score, Body Mass Index (BMI), any pre-operative abdominal surgery (not further specified in the DCRA), tumour related complications, and pathological(p)T-stage. For colon cancer, the location of the tumour within the colon was added to the risk adjustment model, and for rectal cancer the tumour distance from the anal verge, clinical(c)T-stage, pre-operative radiotherapy (no radiotherapy, short course radiotherapy or chemoradiotherapy) and surgical procedure (LAR, APR or other) were added to the risk adjustment model. Further details on the risk adjustment model as used in the DCRA are described in previous studies [17].

Risk stratified analysis of raw data was done to be able to determine the absolute (ARR) and relative risk reductions (RRR) over the years for different subgroups. Ten subgroups of patients were defined based on relevance for surgical treatment (tumour stages: non-locally advanced/non-metastatic (T1-3N0-2M0), locally advanced/non-metastatic (T4N0-2M0) and metastatic (T1-4N0-2M1)) and on known risk factors for postoperative outcomes (ASA score (I–II vs. III–IV) and age (≤ 60 , 61–70, 71–80, ≥ 81 years)).

A *p*-value of less than 0.05 was considered statistically significant. All analyses were performed in SPSS 24.0 Statistics for Windows (Armonk, NY: IBM Corp).

Results

Baseline characteristics

A total of 40,004 colon cancer and 19,853 rectal cancer patients were included for analysis. Table 1 shows the characteristics of colon and rectal cancer patients per two years during the period 2009–2016. For colon and rectal cancer, patients in 2015–2016 compared to 2011–2012 had a higher ASA (III+), Charlson comorbidity score (3+) and BMI(30+).

Table 1

Patient-, tumour- and treatment characteristics of patients with primary CRC undergoing a resection between 2009 and 2016.

Patient		Colon					2015–2016 vs 2011–2012	Rectum				2015–2016 vs 2011–2012
		Year of operation	2009 –2010	2011 –2012	2013 –2014	2015 –2016		P-value	2009 –2010	2011 –2012	2013 –2014	
Total patients		8458	10,357	10,580	10,609			4029	5254	5324	5246	
		N (%)	N (%)	N (%)	N (%)			N (%)	N (%)	N (%)	N (%)	
Age	≤60	1479 (18)	1719 (17)	1759 (17)	1825 (17)	p = 0.610		1057 (26)	1395 (27)	1304 (25)	1366 (26)	p = 0.572
	61–70	2349 (28)	2997 (29)	3140 (30)	3056 (29)			1343 (33)	1760 (34)	1855 (35)	1745 (33)	
	71–80	2894 (34)	3626 (35)	3715 (35)	3707 (35)			1185 (29)	1551 (30)	1566 (29)	1544 (29)	
	≥81	1734 (21)	2013 (19)	1963 (19)	2010 (19)			444 (11)	548 (10)	599 (11)	591 (11)	
Gender	Male	4403 (52)	5422 (52)	5611 (53)	5658 (53)	p = 0.151		2471 (61)	3253 (62)	3380 (64)	3337 (64)	p = 0.077
ASA score	I–II	6301 (76)	7916 (77)	8045 (76)	7782 (73)	p < 0.001		3293 (84)	4383 (84)	4426 (83)	4300 (82)	p = 0.031
	III+	1952 (24)	2419 (23)	2528 (24)	2826 (27)			651 (17)	868 (17)	898 (17)	952 (18)	
Charlson Score	Unknown/missing	205	22	7	1	p < 0.001		86	5	1	1	p < 0.001
	0	4551 (54)	5137 (50)	5009 (47)	4882 (46)			2537 (63)	3047 (58)	2984 (56)	2903 (55)	
	1	1865 (22)	2442 (24)	2483 (24)	2350 (22)			789 (20)	1114 (21)	1103 (21)	1035 (20)	
	2	1187 (14)	1567 (15)	1718 (16)	1732 (16)			446 (11)	652 (12)	770 (15)	781 (15)	
BMI (kg/m2)	3+	833 (10)	1201 (12)	1364 (13)	1624 (15)	p < 0.001		258 (6)	443 (8)	468 (9)	534 (10)	p < 0.001
	Unknown/missing	22	10	6	21			11	3	4	4	
	<18.5	111 (2)	149 (2)	168 (2)	171 (2)			56 (2)	83 (2)	93 (2)	83 (2)	
	18.5–25	2776 (43)	3978 (40)	4154 (40)	4100 (39)			1414 (43)	2046 (40)	2143 (41)	2041 (40)	
	26–30	2510 (39)	4098 (42)	4221 (41)	4077 (39)	p < 0.001		1321 (40)	2136 (42)	2170 (42)	2107 (41)	p < 0.001
	>30	1116 (17)	1656 (17)	1793 (17)	2057 (20)			477 (15)	809 (16)	824 (16)	911 (18)	
	Unknown/missing	1945	476	244	204			762	182	95	111	
	Previous abdominal surgery	Yes	2961 (36)	3696 (36)	3906 (37)		3783 (36)	P = 0.916		1166 (29)	1615 (31)	
Tumour												
Location of Tumour	Ascending colon up to and including hepatic flexure	3885 (46)	4767 (46)	4915 (47)	4905 (46)	p = 0.014						
	Transverse colon up to and including splenic flexure	823 (10)	959 (9)	1048 (10)	1072 (10)							
	Descending colon	450 (5)	583 (6)	562 (5)	659 (6)							
	Sigmoid colon	3300 (39)	4048 (39)	4055 (38)	3973 (37)							
Distance from anal verge	≤5 cm							1385 (37)	1891 (38)	2003 (39)	1926 (37)	p = 0.029
	6–10 cm							1551 (41)	2000 (40)	2009 (39)	2026 (39)	
	>10 cm							814 (22)	1049 (21)	1106 (22)	1210 (23)	
Pre-operative tumour complications	Yes	816 (10)	3152 (31)	3975 (38)	3106 (29)	p = 0.027		280 (287 (7))	316 (1308 (25))	207 (1404 (26))	91 (934 (18))	p < 0.001
Clinical tumour T-stage	cT1							147 (4) (24)	207 (4) (25)	240 (5) (22)	282 (5) (24)	p < 0.001
	cT2							875 (52)	1270 (56)	1154 (61)	1237 (57)	
	cT3							1947 (395)	2855 (434 (9))	3236 (475 (9))	2997 (583)	
	cT4							11 (353 (9))	157 (333 (7))	14 (206 (4))	1 (153 (3))	
Pathological T stage	cTX/Unknown missing (y)pT0–1	679 (8)	927 (9)	959 (9)	1169 (11)	p < 0.001		537 (14)	947 (18)	1056 (20)	1085 (21)	p = 0.005
	(y)pT2	1447 (17)	1841 (18)	1861 (18)	1873 (18)			1240 (32)	1645 (31)	1649 (31)	1543 (30)	
	(y)pT3											

(continued on next page)

Table 1 (continued)

Patient		Colon					2015–2016 vs 2011–2012	Rectum				2015–2016 vs 2011–2012		
		Year of operation				P-value								
		2009 –2010	2011 –2012	2013 –2014	2015 –2016						2009 –2010	2011 –2012	2013 –2014	2015 –2016
Total patients		8458	10,357	10,580	10,609					4029	5254	5324	5246	
		N (%)	N (%)	N (%)	N (%)					N (%)	N (%)	N (%)	N (%)	
Tumour stage (pathological or clinical)*	(y)pT4	5081 (61)	6120 (59)	6190 (59)	5913 (56)	p < 0.001	1911 (49)	2412 (46)	2379 (45)	2375 (45)				
		1088 (13)	1398 (14)	1541 (15)	1627 (15)		237 (6)	224 (4)	223 (4)	219 (4)				
	Unknown/missing	163	71	29	27		105	28	18	31				
	stage 0	69 (1)	175 (2)	71 (1)	47 (0)									
	stage 1	1697 (20)	2097 (20)	2243 (21)	2389 (23)		726 (18)	978 (19)	950 (18)	1121 (21)	P < 0.001			
	stage 2	3159 (37)	3797 (37)	3846 (36)	3766 (35)		787 (20)	986 (19)	1008 (19)	975 (19)				
	stage 3	2495 (29)	3140 (30)	3281 (31)	3374 (32)		1299 (32)	2251 (43)	2700 (51)	2582 (49)				
	stage 4	892 (11)	1067 (10)	1105 (10)	1015 (10)		315 (8)	362 (7)	340 (6)	384 (7)				
	stage X	146 (2)	81 (1)	34 (0)	18 (0)		903 (22)	679 (13)	327 (6)	191 (4)				
	Work-up													
Pre-operative visualisation of entire colon	Yes	5816 (70)	7956 (77)	8666 (82)	8801 (83)	p < 0.001	3032 (78)	4424 (86)	4626 (88)	4521 (87)	P = 0.182			
Patient discussed in MDT	Unknown/missing	192	69	31	23	p < 0.001	159	92	39	31	p < 0.001			
	Yes	4977 (63)	8528 (83)	9835 (94)	10,076 (95)		3520 (91)	5104 (97)	5251 (99)	5188 (99)				
Neo adjuvant chemotherapy (colon)	Unknown/missing	584	134	69	25	p = 0.027	176	15	8	6				
	Yes	95 (1)	201 (2)	228 (2)	253 (2)									
Neo adjuvant radiotherapy (rectum)	Unknown/missing	294	439	409	512	p < 0.001								
	No						760 (20)	869 (17)	1461 (27)	1997 (38)				
	SCRT-IS						1783 (44)	2087 (40)	1429 (27)	828 (16)				
	SCRT-DS						136 (3)	274 (5)	465 (9)	492 (9)				
	CRT/long course						1351 (34)	2026 (39)	1970 (37)	1936 (37)				
Surgery														
Procedure (colon)	Ileocecal resection	106 (1)	122 (1)	89 (1)	59 (1)	p < 0.001								
	Right hemicolectomy	3875 (48)	4778 (47)	5042 (49)	5144 (50)									
	Transverse colon resection	255 (3)	295 (3)	232 (2)	236 (2)									
	Left hemicolectomy	773 (10)	985 (10)	1107 (11)	1102 (11)									
	Sigmoid resection	3128 (38)	3911 (39)	3900 (38)	3838 (37)									
	Unknown/missing	321	266	210	230									
Procedure (rectum)	(Low) anterior resection						2426 (62)	3458 (66)	3496 (66)	3457 (66)	p < 0.001			
	Abdominoperineal resection						1285 (33)	1526 (29)	1515 (29)	1413 (27)				
	Not further specified						202 (5)	224 (4)	282 (5)	358 (7)				
Surgical approach	Unknown/missing						117	48	32	25	p < 0.001			
	Open	4897 (58)	4929 (48)	3477 (33)	2185 (21)	2578 (64)	2527 (48)	1514 (29)	1053 (20)					
	Laparoscopic	3522 (42)	5418 (52)	7079 (67)	8390 (79)	1424 (36)	2724 (52)	3804 (72)	4187 (80)					
Laparoscopic conversion	Unknown/missing	39	10	24	34	p < 0.001	28	5	7	13	p < 0.001			
	No	68 (12)	4366 (86)	6001 (87)	7271 (89)		46 (21)	2089 (86)	3076 (88)	3570 (92)				
	Unknown/missing	2960	312	152	176		1201	294	314	307				

MDT: Multidisciplinary Team Meeting. SCRT: short course radiotherapy with immediate surgery (IS, ≤ 3 weeks) or delayed surgery (DS; > 3 weeks). CRT: chemoradiation therapy. *Pathological stage was used for colon, clinical stage was used for rectum. Stage 0–X includes stage 0 or stage X (unknown or not judgeable).

An overview of 97,254 CRC patients diagnosed with primary CRC in the Netherlands between 2009 and 2015 based on the NCR (2016 not yet available) is provided in Table 2. Total number of patients and corresponding proportions for each specified type of treatment

are displayed for each year, with screening patients included since 2014. The number of elective resections increased, but with a relative decrease of 4% compared to other types of treatment, mainly related to the absolute and relative increase in endoscopic

Table 2

Overview from the Netherlands Cancer Registry (NCR) database of the patients diagnosed with primary colorectal cancer between 2009 and 2015 with their corresponding treatment strategies.

Treatment	Year of diagnosis						
	2009	2010	2011	2012	2013	2014	2015
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Resection - elective	9226 (73)	9368 (72)	9770 (72)	9733 (72)	9391 (71)	10,854 (71)	10,963 (69)
Resection - non-elective	603 (4.8)	588 (4.5)	614 (4.6)	601 (4.4)	605 (4.6)	679 (4.4)	916 (5.7)
Local excision	120 (1)	128 (1)	129 (1)	152 (1.1)	151 (1.1)	240 (1.6)	237 (1.5)
Polypectomy	311 (2.5)	412 (3.2)	385 (2.9)	413 (3)	398 (3)	834 (5.4)	978 (6.1)
(chemo)radiotherapy - no resection	210 (1.7)	262 (2)	315 (2.3)	333 (2.5)	343 (2.6)	375 (2.4)	436 (2.7)
Systemic therapy	873 (6.9)	875 (6.7)	884 (6.6)	889 (6.6)	933 (7)	997 (6.5)	913 (5.7)
radiotherapy and systemic therapy	85 (0.7)	96 (0.7)	124 (0.9)	130 (1)	152 (1.2)	169 (1.1)	160 (1)
Only metastasectomy and/or radiotherapy for metastasis	23 (0.2)	17 (0.1)	19 (0.1)	22 (0.2)	20 (0.2)	24 (0.2)	25 (0.2)
No treatment	1153 (9.1)	1234 (9.5)	1219 (9)	1278 (9.4)	1239 (9.3)	1157 (7.5)	1306 (8.2)
Resection for other indication (incidental finding)	4 (0)	10 (0.1)	10 (0.1)	11 (0.1)	24 (0.2)	30 (0.2)	15 (0.1)
Treatment unknown	13 (0.1)	11 (0.1)	11 (0.1)	10 (0.1)	5 (0)	5 (0)	6 (0)
Total	12,621	13,001	13,480	13,572	13,261	15,364	15,955

2016 was not yet available.

polypectomies of malignant polyps. The shift towards more local treatments of CRC can probably be contributed to the start of the screening program in 2014.

Postoperative outcomes

Overall, postoperative complicated course and mortality decreased 3.0% and 1.6% in colon cancer, respectively, and 3.8% and 1.3% in rectal cancer, respectively, since 2011–2012. For colon cancer, multivariable analysis showed a significant reduction in the risk of a complicated postoperative course (AOR 0.74, 95% CI 0.69–0.80), as well as the risk of postoperative mortality (AOR 0.49, 95% CI 0.41–0.59). Similarly, a reduction was found for reinterventions for a surgical complication in 2015–2016 compared to 2011–2012 (Adjusted Odds Ratio (AOR) 0.67, 95% Confidence interval (CI) 0.58–0.77) (Table 3). The risk of non-surgical

complications significantly increased between 2011–2012 and 2015–2016 (AOR 1.15, 95% CI 1.07–1.24).

For rectal cancer, multivariable analysis showed a significant decrease for complicated postoperative course (AOR 0.80, 95% CI 0.72–0.88) and mortality (AOR 0.41, 95% CI 0.29–0.57) when comparing 2015–2016 with 2011–2012 (Table 3). A significant increase was found for non-surgical (AOR 1.18, 95% CI 1.06–1.30) and surgical (AOR 1.15, 95% CI 1.04–1.27) complications, without a significant difference in reinterventions for surgical complications (AOR 0.90, 95% CI 0.67–1.21).

Risk stratified comparison of outcomes

Fig. 1 shows the ARR and RRR for each of the predefined 10 subgroups when comparing postoperative outcomes after colon cancer resection in the period 2015–2016 with 2011–2012

Table 3

Uni- and multivariable analysis for the odds on different post-operative outcomes for the 2015–2016 compared to 2011–2012.

Outcomes	Year of operation		ARR (95% CI)	Year of operation		
	2011–2012	2015–2016		2011–2012	2015–2016	Odds ratio (CI)
	Patients N (%)	Patients N (%)				
Colon †*	Complicated course	1753/10,357 (16.9)	1478/10,609 (13.9)	3.0% (2.02–3.98)	Univariable Ref	0.79 (0.74–0.86)
				Multivariable Ref		0.74 (0.69–0.80)
	Mortality	347/10,357 (3.4%)	193/10,609 (1.8%)	1.6% (1.17–2.04)	Univariable Ref	0.54 (0.45–0.64)
				Multivariable Ref		0.49 (0.41–0.59)
	Surgical complications	1656/10,357 (16.0)	1838/10,609 (17.3)	–1.3% (–0.29 to –2.31)	Univariable Ref	1.10 (1.02–1.18)
				Multivariable Ref		1.05 (0.98–1.13)
	Reintervention for Surgical complication	1018/1651 (61.5)	944/1838 (51.4)	10.1% (6.81–13.36)	Univariable Ref	0.66 (0.57–0.75)
				Multivariable Ref		0.67 (0.58–0.77)
	Non-surgical complications	1714/10,357 (16.5)	2011/10,609 (19.0)	–2.5% (–1.47 to –3.53)	Univariable Ref	1.18 (1.10–1.27)
				Multivariable Ref		1.15 (1.07–1.24)
Rectum †*	Complicated course	1205/5256 (22.9)	1001/5253 (19.1)	3.8% (2.24–5.35)	Univariable Ref	0.79 (0.72–0.87)
				Multivariable Ref		0.80 (0.72–0.88)
	Mortality	120/5256 (2.3)	54/5253 (1.0)	1.3% (0.82–1.80)	Univariable Ref	0.45 (0.32–0.61)
				Multivariable Ref		0.41 (0.29–0.57)
	Surgical complications	1129/5256 (21.5)	1233/5253 (23.5)	2.0% (0.40–3.60)	Univariable Ref	1.12 (1.02–1.23)
				Multivariable Ref		1.15 (1.04–1.27)
	Reintervention for Surgical complication	672/1129 (59.5)	627/1233 (50.9)	8.6% (4.59–12.57)	Univariable Ref	0.70 (0.60–0.83)
				Multivariable Ref		0.90 (0.67–1.21)
	Non-surgical complications	1056/5256 (20.1)	1176/5253 (22.4)	–2.3% (–0.74 to –3.86)	Univariable Ref	1.15 (1.05–1.26)
				Multivariable Ref		1.18 (1.06–1.30)

The ARR (Absolute Risk Reduction) and RRR (Relative Risk Reduction) of the outcomes of colon cancer for the years 2015–2016 compared to 2011–2012. †The following factors were included in the multivariable model to correct for differences in case mix between patients; sex, age, ASA, Charlson comorbidity score, BMI, previous abdominal surgery, tumour related complications, pT-classification. ‡Added for the colon: location of tumour. #Added for the rectum: received radiotherapy (non, short course or chemo-radiation), procedure (LAR, APR or different), cT-classification, tumour distance from anal verge. *Missing colon (N = 68(0.3%)) or rectal (N = 437 (4.2%)) cancer patients in corresponding multivariable logistic regression (missing rectal cancer patients primarily consisting of missing tumour distance to anal verge: n = 407). Bold = significant difference.

Fig. 1. The ARR (Absolute Risk Reduction) and RRR (Relative Risk Reduction) of different outcomes of colon cancer treatment for the years 2015–2016 compared to 2011–2012, risk-stratified for different subgroups (1–10). BR = Baseline Risk in 2011–2012 for the outcome of interest. The numbers in the figure are the ARR for all corresponding subgroup and outcome. For readmissions, BR of the years 2012–2013 is used because this was not measured prior to 2012. *significant difference ($p < 0.05$) for 2015–2016 compared to 2011–2012 (and 2012–2013 for readmission).

(2012–2013 for readmission due to availability in the dataset). Fig. 2 is showing the same for rectal cancer.

In colon cancer, the risk on a complicated postoperative course was lower in nine subgroups, with the largest ARR of 6.4% (RRR 22.3%) in high risk elderly patients (group 8; T1-3N0-2M0, ≥ 81 yrs, ASA III–IV). The ARR on postoperative mortality was lower for all subgroups, with again the largest ARR of 5.9% (RRR 52.8%) in the high-risk elderly patients (group 8). Surgical as well as non-surgical complications showed a slight increase in most subgroups, but mostly not statistically significant. The risk of undergoing a reintervention for a surgical complication decreased in all subgroups, with a significant ARR of 15.8% in the high-risk elderly patients (group 8). Readmissions did not markedly change.

For rectal cancer, a reduced risk of complicated postoperative course was observed in nine subgroups, with the largest ARR of -20.0% (RRR 53.8%) in group 5 (T1-3N0-2M0, ≤ 60 yrs, ASA III–IV). The ARR on mortality was lower for all subgroups, with patients of group 7 (T1-3N0-2M0, 71–80 yrs, ASA III–IV) having the highest ARR of 6.0% (RRR 71.8%). As in colon cancer, similar changes over time were observed for the other outcome parameters, with reduction in reintervention for all subgroups and a highest ARR of 28.6% for group 7 (T1-3N0-2M0, 71–80 yrs, ASA III–IV).

Overall, median postoperative LOS decreased from 7 to 5 days for colon ($p < 0.001$) and from 8 to 6 days for rectal cancer ($p < 0.001$). Fig. 3 shows that the median decrease in LOS, with its corresponding distribution, was significant in 9 out of 10 subgroups in both colon and rectal cancer patients. The largest decrease in the

Fig. 2. The ARR (Absolute Risk Reduction) and RRR (Relative Risk Reduction) of different outcomes of rectal cancer treatment for the years 2015–2016 compared to 2011–2012, risk-stratified for different subgroups (1–10). BR = Baseline Risk in 2011–2012 for the outcome of interest. The numbers in the figure are the ARR for the corresponding subgroup and outcome. For readmissions, BR of the years 2012–2013 is used because this was not measured prior to 2012. *significant difference ($p < 0.05$) for 2015–2016 compared to 2011–2012 (and 2012–2013 for readmission).

75th interquartile range (IQR) in both colon and rectal cancer was found for group 7 (T1-3N0-2M0, 71–80 yrs, ASA III–IV). Their 75th IQR percentage dropped from 14 to 10 days and from 19 to 12 days, respectively.

Trends in surgical procedures for rectal cancer

Comparing 2011 with 2016, the proportion of patients receiving a diverting stoma after a (L)AR with primary anastomosis decreased from 51.3% to 40% (Fig. 4A). Also, (L)AR with end-colostomy (Hartmann's procedure) decreased from 26.3% to 19.4%. In contrast, the proportion of (L) AR with primary anastomosis without diverting stoma increased from 22% to 40.4%. Reintervention for anastomotic leakage was 5.6% in 2011 and 6.0% in 2016.

In low rectal cancer (≤ 5 cm from the anal verge), patients increasingly received a non-diverted primary anastomosis (5.4% in

2011 and 14.4% in 2016; Fig. 4B). The proportion of reintervention for anastomotic leakage in low rectal cancer did not change: 2.3% in 2011 and 2.4% in 2016. The proportions of both APR and LAR with end-colostomy (Hartmann's procedure) decreased over the years 2011–2016, from 66.3% to 50.8% and 14.2%–10.3%, respectively.

Discussion

This study provides insights in eight years of auditing of CRC surgery in the Netherlands. The risk profile of patients undergoing surgery for primary CRC remained largely unchanged, with even a slight increase in ASA, Charlson comorbidity score and BMI. In addition, NCR data did not suggest that patients were not registered in the DCRA or not operated upon because of high risk (risk aversion). Only small changes in surgical treatment were observed, mainly related to introduction of screening in 2014.

Fig. 3. Length of stay (LOS) until discharge or in hospital death. LOS is shown as the median in days with its corresponding interquartile range (25th and 75th quartile around median). Median LOS in 2011–2012 and 2015–2016 are shown for each risk-stratified subgroup (1–10) and for colon and rectum separately. *significant difference ($p < 0.05$) between 2015–2016 vs 2011–2012, tested with a non-parametric Mann Whitney U test.

Fig. 4. Stoma construction for (low) anterior resections and low rectal tumours for the years 2011–2016. **A.** Differences in the construction of a stoma and surgical reintervention for an anastomotic leakage after a (Low) Anterior Resection for the years 2011–2016. **B.** Development in treatment modalities and surgical reintervention for an anastomotic leakage for low rectal tumours (tumours ≤ 5 cm from the anal verge) for the years 2011–2016.

Overall improvements in mortality and complicated post-operative course were seen. Remarkably, both surgical and non-surgical complication rates did not reduce and even revealed a slight increase for several subgroups of patients. However, surgical complications seemed to become less severe in both colon and rectal cancer surgery, as illustrated by the reduced reintervention rates. The high-risk elderly patients appeared to have benefitted the most from improvements made in CRC treatment. Regarding surgical procedures for rectal cancer, a reduction in construction of temporary diverting stomas and end-colostomies was observed, even for the group of patients with low rectal cancer. The unchanged risk profiles of patients and the striving for more

bowel continuity in rectal cancer by surgeons did not suggest any risk aversion.

Postoperative mortality is one of the most important quality indicators in CRC surgery. Overall, postoperative mortality decreased from 3.4% to 1.8% in colon cancer and from 2.3% to 1% in rectal cancer since 2011. The largest absolute risk reduction in mortality was achieved in the patients at highest operative risk; from 11.2% to 5.3% (ARR 5.9%) in colon cancer patients of ≥81 years and ASA III–IV, and from 8.4% to 2.4% (ARR 6.0%) in rectal cancer patients of 71–80 years and ASA III–IV. However, smaller improvements in other patient categories might have a significant impact if it concerns a substantial population in absolute numbers.

In line with the findings of Henneman et al., who already showed that non-surgical complications were a target for improvement based on DCRA data between 2011 and 2012 [1], we found a further increase in complication rate. Better registration or better recognition of complications [18] could have contributed to this observation. Furthermore, baseline characteristics revealed a slight increase in comorbidity and BMI, which might increase the a priori risk of postoperative complications. Nevertheless, one would have expected any impact of increased awareness and several improvement measures in perioperative care (i.e. prehabilitation, Enhanced Recovery After Surgery (ERAS), geriatric consultation) on this outcome parameter. Therefore, non-surgical complications should remain an area of attention for the coming years. However, complications seem to become less severe and probably better managed considering the observed decreases in reinterventions for a surgical complication, LOS and postoperative mortality. This also explains the observed improvements for the composite endpoint of complicated postoperative course. This benefits both the patients as well as the healthcare system, as severe complications are large cost drivers, aside from the initial treatment [19].

Platell et al. showed that patients with benign and malignant diseases undergoing a low anterior resection with an anastomosis within 5 cm from the anal verge are the highest risk group for an anastomotic leak, with ultra-low anterior anastomoses having the highest (8%) risk of a leak [20]. The systematic review of Huser et al. showed that constructing a diverting stoma in patients undergoing a low anterior resection reduces the rate of clinically relevant anastomotic leakage [21]. However, like Snijder et al. also previously demonstrated, despite the decreasing construction of a (diverting) stoma, we found no difference in the rate of reintervention for anastomotic leakage over time, [22]. Furthermore, this finding contrasts with the suggested existence of a risk averse strategy by surgeons promoted through nationwide auditing. In fact, auditing might have been one of the driving forces behind further specialization of surgeons, thereby improving the capability of managing high risk patients. Decreasing rates of APR and Hartmann's procedure in distal rectal cancer are likely an effect of this specialization. This is also illustrated by the increase in the use of laparoscopic surgery for both colon and rectal cancer resection. In a previous study, we hypothesized that lower mortality rates after minimally invasive surgery compared to open surgery might not purely be related to the surgical technique, but also reflects expertise of surgeons and the hospital setting in which the procedure is performed [23].

In our study, we found a decreased LOS for colon as well as for rectal cancer, without an increase in readmission. In agreement with Pucciarelli et al. [24] and other studies [25], patients with colon cancer were at lower risks of a prolonged LOS and 30-day readmission compared to with rectal cancer. Damle et al. looked at the 30-days readmissions of colorectal resections for multiple indications and found half of the readmissions occurring within 7 days, with readmitted patients costing double compared to those not being readmitted [26]. Furthermore, Greenblatt et al. found an association between readmissions and 1-year mortality after colectomy for cancer (OR 2.44, 95% CI 2.25–2.65). The lower LOS and readmission rates again benefits both the patients as well as the healthcare system.

One can imagine that the success of an audit depends largely on the quality and intelligibility of the feedback data, as well as on the users' appreciation of the received data and own efforts in putting it into practise in the form of improvement cycles [27,28]. When interpreting the results, it is important to realize that the outcome measures are only externally reported on a hospital level and not, as might be the case in other audits, on surgeon level. Besides, as in many examples of observational research, causality is a major issue.

Without a control group, the possible impact of auditing cannot be proved. It cannot be excluded that time itself is a confounder and that improvements would have occurred without auditing and re-reporting. The relative contribution to the improvements of evolving insights and techniques, such as the impact of surgical centralization and specialization [29] and the increasing use of new techniques such as laparoscopic surgery [23,30], is almost impossible to quantify when looking at overall trends in time. However, the consistency of demonstrated trends suggests that auditing matters and leads to new insights. Furthermore, substantial improvements in process indicators within a relatively short time period, such as preoperative MDT discussion, MRI imaging in rectal cancer and reporting of CRM, can without a doubt be attributed to auditing [12]. Besides, auditing facilitates international comparison on treatment patterns and outcomes, enabling valuable discussions about inter-hospital variability and identifying best practise [31]. An example of this was the observed overtreatment by preoperative radiotherapy in the Netherlands compared to other countries, with substantial inter-hospital variability [32], leading to guideline revision, with subsequent rapid implementation as monitored by the DCRA [33].

The strength of this study is the large numbers of patients and external validity related to the population-based data reflecting daily practise. But there are also some limitations. A certain degree of missing data is inevitable in population-based studies. Considering risk adjustment, there is always a possibility that not all contributing factors were included. For the purpose of this study, we decided to exclude patients referred through the national colorectal cancer screening program. This may have led to an underestimation of the demonstrated improvements. Also, a better registration over the years and training of surgeons/data-managers could have had a certain influence on the reported data. Finally, the DCRA does not provide information beyond 30 days or admission.

Conclusion

An overall improvement of outcomes has been demonstrated during the period of auditing, without signs of risk averse behaviour (e.g. patient selection). Although the severity of complications is decreasing, areas of future attention remain the surgical and non-surgical complications. In colon cancer, especially the high-risk elderly patients have benefitted most of the improvements made in the past 8 years. For rectal cancer, an increasing trend is seen in the proportion of (L)AR with primary anastomosis without diverting stoma and decreasing rates of APR and low Hartmann's procedure in distal rectal cancer, possibly reflecting specialization.

Conflicts of interest statement

We have no conflict of interest to declare.

Additional information and declarations

Authorship statement

The following are members of the Dutch ColoRectal Audit Group: R.G.H. Beets-Tan, W.A. Bemelman, D. Boerma, P.P. Coenen, E. Dekker, E.H. Eddes, H. Gelderblom, E. van der Harst, T.M. Karsten, J.H. van Krieken, N.J. van Leersum, V.E. Lemmens, W.J. Meijerink, E.R. Manusama, C.A.M. Marijnen, I.D. Nagtegaal, C.J. van de Velde, T. Wiggers.

Availability of data and material

The data that support the findings of this study are available from the Dutch Institute for Clinical Auditing (DICA) but are not publicly available. Data are however available from the authors upon reasonable request and with permission of the Dutch Institute for Clinical Auditing and the Dutch ColoRectal Audit Board.

Ethics approval and consent to participate

The DCRA comprises an obligatory audit from the inspectorate of healthcare, which required no informed consent from patients for data collection. Data analyses were performed on an anonymized dataset and does not need ethical approval according to Dutch law.

References

- [1] Henneman D, Ten Berge MG, Snijders HS, van Leersum NJ, Fiocco M, Wiggers T, et al. Safety of elective colorectal cancer surgery: non-surgical complications and colectomies are targets for quality improvement. *J Surg Oncol* 2014;109:567–73.
- [2] Hu CY, Bailey CE, You YN, Skibber JM, Rodriguez-Bigas MA, Feig BW, et al. Time trend analysis of primary tumor resection for stage IV colorectal cancer: less surgery, improved survival. *JAMA Surg* 2015;150:245–51.
- [3] Iversen LH, Green A, Ingeholm P, Osterlind K, Gogenur I. Improved survival of colorectal cancer in Denmark during 2001–2012–The efforts of several national initiatives. *Acta Oncol* 2016;55(Suppl. 2):10–23.
- [4] van Gijn W, van de Velde CJ. Improving quality of cancer care through surgical audit. *Eur J Surg Oncol* 2010;36(Suppl. 1):S23–6.
- [5] Habib MR, Solomon MJ, Young JM, Armstrong BK, O'Connell D, Armstrong K. Evidence-based and clinical outcome scores to facilitate audit and feedback for colorectal cancer care. *Dis Colon Rectum* 2009;52:616–22. Discussion 22–23.
- [6] Cheung A, Weir M, Mayhew A, Kozloff N, Brown K, Grimshaw J. Overview of systematic reviews of the effectiveness of reminders in improving healthcare professional behavior. *Syst Rev* 2012;1:36.
- [7] Patwardhan MB, Samsa GP, McCrory DC, Fisher DA, Mantyh CR, Morse MA, et al. Cancer care quality measures: diagnosis and treatment of colorectal cancer. *Evid Rep Technol Assess Full Rep* 2006;1–116.
- [8] Benjamin A. Audit: how to do it in practice. *BMJ* 2008;336:1241–5.
- [9] Smith R. Audit and research. *BMJ* 1992;305:905–6.
- [10] Wibe A, Moller B, Norstein J, Carlsen E, Wiig JN, Heald RJ, et al. A national strategic change in treatment policy for rectal cancer—implementation of total mesorectal excision as routine treatment in Norway. A national audit. *Dis Colon Rectum* 2002;45:857–66.
- [11] Ivers N, Jamtvedt G, Flottorp S, Young JM, Odgaard-Jensen J, French SD, et al. Audit and feedback: effects on professional practice and healthcare outcomes. *Cochrane Database Syst Rev* 2012 Jun 13;(6), CD000259. <https://doi.org/10.1002/14651858.CD000259.pub3>.
- [12] Van Leersum NJ, Snijders HS, Henneman D, Kolfshoten NE, Gooiker GA, ten Berge MG, et al. The Dutch surgical colorectal audit. *Eur J Surg Oncol* 2013;39:1063–70.
- [13] Elferink MA, Wouters MW, Krijnen P, Lemmens VE, Jansen-Landheer ML, van de Velde CJ, et al. Disparities in quality of care for colon cancer between hospitals in The Netherlands. *Eur J Surg Oncol* 2010;36(Suppl. 1):S64–73.
- [14] van Leersum NJ, Aalbers AG, Snijders HS, Henneman D, Wouters MW, Tollenaar RA, et al. Synchronous colorectal carcinoma: a risk factor in colorectal cancer surgery. *Dis Colon Rectum* 2014;57:460–6.
- [15] Amri R, Bordeianou LG, Sylla P, Berger DL. Impact of screening colonoscopy on outcomes in colon cancer surgery. *JAMA Surg* 2013;148:747–54.
- [16] Birthyears invited per year for the Dutch Colorectal Screening program. http://www.rivm.nl/Documenten_en_publicaties/Algemeen_Actueel/Brochures/Preventie_Ziekte/Darmkanker/Uitnodigingsoverzicht_bevolkingsonderzoek_darmkanker
- [17] Kolfshoten NE, Marang van de Mheen PJ, Gooiker GA, Eddes EH, Kievit J, Tollenaar RA, et al. Variation in case-mix between hospitals treating colorectal cancer patients in The Netherlands. *Eur J Surg Oncol* 2011;37:956–63.
- [18] van Vugt JL, Reisinger KW, Derikx JP, Boerma D, Stoot JH. Improving the outcomes in oncological colorectal surgery. *World J Gastroenterol* 2014;20:12445–57.
- [19] Govaert JA, Fiocco M, van Dijk WA, Scheffer AC, de Graaf EJ, Tollenaar RA, et al. Costs of complications after colorectal cancer surgery in The Netherlands: building the business case for hospitals. *Eur J Surg Oncol* 2015;41:1059–67.
- [20] Platell C, Barwood N, Dorfmann G, Makin G. The incidence of anastomotic leaks in patients undergoing colorectal surgery. *Colorectal Dis* 2007;9:71–9.
- [21] Huser N, Michalski CW, Erkan M, Schuster T, Rosenberg R, Kleeff J, et al. Systematic review and meta-analysis of the role of defunctioning stoma in low rectal cancer surgery. *Ann Surg* 2008;248:52–60.
- [22] Snijders HS, van Leersum NJ, Henneman D, de Vries AC, Tollenaar RA, Stiggelbout AM, et al. Optimal treatment strategy in rectal cancer surgery: should we be cowboys or chickens? *Ann Surg Oncol* 2015;22:3582–9.
- [23] Gietelink L, Wouters MW, Bemelman WA, Dekker JW, Tollenaar RA, Tanis PJ. Reduced 30-day mortality after laparoscopic colorectal cancer surgery: a population based study from the Dutch surgical colorectal audit (DSCA). *Ann Surg* 2016;264:135–40.
- [24] Pucciarelli S, Zorzi M, Gennaro N, Gagliardi G, Restivo A, Saugo M, et al. In-hospital mortality, 30-day readmission, and length of hospital stay after surgery for primary colorectal cancer: a national population-based study. *Eur J Surg Oncol* 2017;43:1312–23.
- [25] Faiz O, Haji A, Burns E, Bottle A, Kennedy R, Aylin P. Hospital stay amongst patients undergoing major elective colorectal surgery: predicting prolonged stay and readmissions in NHS hospitals. *Colorectal Dis* 2011;13:816–22.
- [26] Damle RN, Cherng NB, Flahive JM, Davids JS, Maykel JA, Sturrock PR, et al. Clinical and financial impact of hospital readmissions after colorectal resection: predictors, outcomes, and costs. *Dis Colon Rectum* 2014;57:1421–9.
- [27] Bradley EH, Holmboe ES, Mattera JA, Roumanis SA, Radford MJ, Krumholz HM. Data feedback efforts in quality improvement: lessons learned from US hospitals. *Qual Saf Health Care* 2004;13:26–31.
- [28] Larson EL, Patel SJ, Evans D, Saiman L. Feedback as a strategy to change behaviour: the devil is in the details. *J Eval Clin Pract* 2013;19:230–4.
- [29] Oliphant R, Nicholson GA, Horgan PG, Molloy RG, McMillan DC, Morrison DS. Contribution of surgical specialization to improved colorectal cancer survival. *Br J Surg* 2013;100:1388–95.
- [30] Kolfshoten NE, van Leersum NJ, Gooiker GA, Marang van de Mheen PJ, Eddes EH, Kievit J, et al. Successful and safe introduction of laparoscopic colorectal cancer surgery in Dutch hospitals. *Ann Surg* 2013;257:916–21.
- [31] van den Broek CB, van Gijn W, Bastiaannet E, Moller B, Johansson R, Elferink MA, et al. Differences in pre-operative treatment for rectal cancer between Norway, Sweden, Denmark, Belgium and The Netherlands. *Eur J Surg Oncol* 2014;40:1789–96.
- [32] van Leersum NJ, Snijders HS, Wouters MW, Henneman D, Marijnen CA, Rutten HR, et al. Evaluating national practice of preoperative radiotherapy for rectal cancer based on clinical auditing. *Eur J Surg Oncol* 2013;39:1000–6.
- [33] Gietelink L, Wouters M, Marijnen CAM, van Groningen J, van Leersum N, Beets-Tan RGH, et al. Changes in nationwide use of preoperative radiotherapy for rectal cancer after revision of the national colorectal cancer guideline. *Eur J Surg Oncol* 2017;43:1297–303.