The impact of hospital volume on perioperative outcomes of rectal cancer

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ABSTRACT

Introduction

The purpose of this study was to investigate the impact of hospital volume on perioperative outcomes of clinical tumour stage (cT)1-3 rectal and cT4 rectal cancer.

Methods

16.162 patients operated for rectal cancer enrolled in the Dutch Surgical Colorectal Audit were included. Hospitals were divided into low (< 20 cases/year), medium (21-50 cases/year) and high (> 50 cases/year) volume for cT1-3 rectal cancer, and for cT4 rectal cancer into low (1-4 cases/year), medium (5-9 cases/year) and high (≥ 10 cases/year) volume. The influence of hospital volume on perioperative outcomes was investigated.

Results

With regards to cT1-3 tumours, low volume hospitals had lower rates of complications (33.8% vs. 36.6% and 38.1%, p = 0.009), anastomotic leakage (5.4% vs. 8.1% and 8.6%), and reintervention (11.5% vs. 12.6% and 14.8%, p = 0.002) as compared to medium and high volume hospitals. Thirty-day mortality and R0 rates were comparable between groups.

In high cT4 volume hospitals, rates of extensive resection of tumour involvement (49.4% vs. 25.4% and 15.5%, p < 0.001) and additional resection of metastasis (17.5% vs. 14.4% and 3.0%, p < 0.001) were increased as compared to medium and low volume hospitals. Thirty-day mortality and R0 rates were comparable between groups. In a sub-analysis of pathologic tumour stage 4 patients, irradical resections were increased in low volume hospitals (33.8% vs. 22.5% and 20.8% in medium and high volume hospitals, p = 0.031).

Conclusions

For cT4 rectal cancer, high volume hospitals may offer a better multimodality treatment, while for cT-3 rectal cancer there appears no benefit for centralization.

INTRODUCTION

The introduction of standardized total mesorectal excision (TME) and neoadjuvant therapies has led to improved oncological results after low anterior resection (LAR) for rectal cancer.(1, 2) The primary goal of surgical treatment of rectal cancer is to achieve a radical resection (R0) since a positive circumferential resection margin (CRM) is a poor prognostic factor, associated with local recurrence, distant metastasis, and inferior survival after rectal cancer surgery.(3, 4) Generally, neoadjuvant (chemo) radiotherapy is administered for the more advanced stages of rectal cancer, to induce tumour shrinkage to facilitate complete resections and reduce local recurrence rates.(5, 6) Neoadjuvant treatment is usually not necessary for lower stages of rectal cancer, which can be treated by standard TME procedures or even rectal sparing surgery in selected patients.(5, 6, 7) The most advanced stage of rectal cancer, including clinically staged 4 tumours (cT4) invading the mesorectal fascia and/or surrounding organs, often require an induction treatment for tumour downsizing and a more radical surgical approach to achieve a complete resection. These procedures, such as extralevatory abdominoperineal resections (APR) and exenterative procedures, require a more complex surgical dissection beyond the standard TME plane.(8)

In order to further improve the outcome of rectal cancer, the current Dutch standard indicates an overall minimum of 20 rectal resections annually per hospital, irrespective of the tumour stage. In addition, the Dutch guideline recommends centralization of care for patients with advanced stages of rectal cancer in specialized colorectal cancer hospitals.(9) The impact of hospital volume on surgical outcomes after rectal cancer surgery are under debate. A recent population-based study revealed no differences in 5-year survival rates between hospital volumes for patients with colorectal cancer; however, outcomes were not stratified for rectal cancer, nor for tumour stage.(10) Little is known regarding the exact effects of hospital volume on different cT1-T4 stages of rectal cancer. The purpose of this study was to evaluate the impact of hospital volume on surgical resection and perioperative outcomes of cT1-3 rectal cancer and cT4 rectal cancer using data from a national registry.

METHODS

DSCA

All patients undergoing resection of colorectal cancer in the Netherlands are since 2009 registered in the Dutch Surgical Colorectal Audit (DSCA). The DSCA was initiated by the Dutch Surgical Society to monitor and improve the quality of oncological care in colorectal cancer patients on a national level.(11) Nowadays, all 92 Dutch hospitals participate in the DSCA and its data shows a nearly 100% concordance on validation against the Na-

tional Cancer Registry dataset.(12) Data on patient and tumour characteristics, diagnostics, treatment and short term outcome were collected. Medical ethics committee approval was not required for this study as all patients and hospital information in the DSCA was de-identified. Individual patient data were collected in the treating hospital and transferred in encrypted form to the DSCA database.

Patient selection

All patients operated for rectal cancer, defined as a tumour within 15 cm of the anal verge, enrolled in the DSCA between January 2009 and December 2015 were included. Overall, 19.354 patients with presumed rectal cancer were enrolled in the DSCA. After excluding tumours > 15 cm of the anal verge, those with unknown distance between tumour and anal verge, unknown procedures, or other procedures than rectal cancer surgery (i.e. left-sided colectomy), 17.477 patients remained. After excluding tumours with unknown clinical tumour stage, 16.162 patients remained.

Patients with cT1-3 tumours were stratified based on median annual cT1-3 hospital volume, which was defined as low volume (0-19 cases/year), medium volume (20-50 cases/year) or high volume (> 50 cases/year). In addition, cT4 tumours were stratified based on median annual cT4 hospital volume, which was defined as low volume (0-4 cases/year), medium volume (5-9 cases/year), or high volume (> 9 cases/year). Subsequently, baseline and operative characteristics, pathologic and postoperative outcomes were compared between cT1-3 hospital volume groups, and cT4 hospital volume groups.

Data analysis

Missing data were not defaulted to negative and denominators reflect only actual reported cases. Nominal variables were compared between groups using the Chi-square test, continuous variables using the One-Way ANOVA test. Multivariable regression analysis was performed to investigate independent effects of hospital volume on a complicated course after resection of cT4 rectal cancer. Hospital volume and variables that were significant in univariable analysis ($p < 0.05$), were included in a multivariable logistic regression model to determine independent associations with this endpoint. SPSS 22 was utilized for the analyses, and a ***P*** value < 0.05 was considered significant. The STROBE guidelines were used to ensure the reporting of this observational study.(13)

RESULTS

Overall, 14.651 patients (90.7%) had clinical tumour stage 1, 2 or 3, of which 3.210 (21.9%) were operated in 39 low volume hospitals; 8730 (59.6%) were operated in 44

medium volume hospitals, and 2.711 patients (18.5%) were operated in 8 high volume hospitals. In addition, there were 1.511 (9.3%) patients with clinical tumour stage 4 (cT4), of which 759 (50.2%) were operated in 72 low volume hospitals; 336 (22.2%) were operated in 8 medium volume hospitals, and 416 (27.5%) were operated in 3 high volume hospitals.

Clinical tumour stage 1-3

Baseline and operative characteristics

Fewer cT1-3 patients underwent neoadjuvant therapy in high volume hospitals (72.7% vs. approximately 75% in medium and high volume hospitals, p = 0.026). Clinical tumour stage 3 was more common in medium volume hospitals, while clinical nodal stage 0 was more frequently seen in low volume hospitals (p < 0.001). An abdominoperineal resection was more often performed in medium (28.1%) and high volume hospitals (27.8%) as compared to low volume hospitals (26.4%, p < 0.001). A laparoscopic approach was slightly more common in low volume hospitals, while resection of synchronous metastases was more frequently performed in medium volume hospitals (Table 1).

Postoperative outcomes

In high volume hospitals, pathologic tumour stage 3 was more often found. A radical resection was achieved in 96.7% and did not differ significantly between the three volume groups (Table 2). A complicated course was more often seen in high volume hospitals (38.1% vs. 33.8% and 36.6% in low and medium volume hospitals, respectively, p = 0.009). Reintervention including (re)laparotomy were more frequently performed in high volume hospitals (14.8% vs, 11.5% and 12.6% in low and medium hospitals (p = 0.002). Anastomotic leakage after LAR was lower in low volume hospitals (5.4% vs. 8.1% and 8.6% in medium and high volume hospitals, respectively, p = 0.001). The overall 30-day mortality rate was 1.9% and did not differ significantly between groups, while the median length of stay was one day longer in high volume hospitals (Table 2).

Clinical tumour stage 4

Baseline and operative characteristics

Mean age of cT4 patients was lower in high volume hospitals and these were less frequently classified as ASA 3 or 4, but more often discussed in multidisciplinary tumour board (MDT) meetings preoperatively (Table 3). Overall, neoadjuvant therapies were less frequently offered in high volume hospitals, while cT4 patients did receive more often chemoradiotherapy in these clinics (69.2% vs. 66.4% and 65.0% in low and medium

Table 1. Baseline and operative characteristics of cT1-3 rectal cancer patients

	Low volume (0-19) N=3210 (21.9%)	**Medium volume (20-50) N=8730 (59.6%)**	**High volume (>50) N=2711 (18.5%)**	P value
Age (y)	68.1±10.7	67.1±10.7	67.5±10.4	<0.001
Male gender	2030 (63.3%)	5674 (65.0%)	1740 (64.2%)	0.195
BMI	26.3±4.1	26.3±4.1	26.2±4.1	0.673
Medical history				
Cardiac	719 (31.1%)	1934 (32.0%)	597 (30.6%)	0.633
Vascular	1153 (51.4%)	3153 (52.1%)	1010 (51.7%)	0.832
Pulmonal	409 (18.3%)	1017 (16.9%)	341 (17.5%)	0.125
Diabetes	446 (20.0%)	1197 (19.8%)	358 (18.3%)	0.159
Neurologic	340 (15.2%)	1011 (16.8%)	325 (16.6%)	0.222
ASA class 3 or 4	584 (18.4%)	1366 (15.7%)	459 (16.9%)	0.001
MDT meeting preoperative	3080 (96.0%)	8464 (97.1%)	2631 (97.1%)	<0.001
Neoadjuvant therapy	2392 (75.3%)	6555 (75.2%)	1964 (72.7%)	0.026
Short-course (5x5 Gy)	1468 (46.2%)	3433 (39.6%)	1169 (43.3%)	
Long-course	107 (3.4%)	261 (3.0%)	46 (1.7%)	
Chemoradiotherapy	816 (25.7%)	2803 (32.4%)	746 (27.7%)	<0.001
cT stage				
cT1	160 (5.0%)	475 (5.4%)	173 (6.4%)	
cT2	965 (30.1%)	2226 (25.5%)	908 (33.5%)	
cT3	2085 (65.0%)	6029 (69.1%)	1630 (60.1%)	<0.001
cN stage				
cN0	1585 (51.9%)	3889 (46.6%)	1180 (44.7%)	
cN1	1043 (34.2%)	2784 (33.3%)	961 (36.4%)	
cN2	426 (13.9%)	1677 (20.1%)	498 (18.9%)	<0.001
cM1	102 (3.8%)	624 (7.2%)	156 (5.8%)	<0.001
Distance to anal verge (cm)	7.5±4.1	7.3±4.2	7.4±4.2	0.079
Operative characteristics				
LAR	1701 (53.1%)	4436 (50.8%)	1399 (51.6%)	
Low Hartmann	604 (18.8%)	1504 (17.2%)	445 (16.4%)	
APR	847 (26.4%)	2453 (28.1%)	753 (27.8%)	
Different	54 (1.7%)	332 (3.8%)	114 (4.2%)	<0.001
Elective resection	3132 (97.6%)	8610 (98.7%)	2674 (98.7%)	<0.001
Laparoscopic	2018 (63.1%)	5171 (59.3%)	8891 (60.8%)	<0.001
Additional resection metastasis	23 (0.7%)	265 (3.1%)	43 (1.7%)	<0.001
Blood transfusion needed	297 (9.6%)	921 (11.0%)	200 (7.7%)	<0.001

BMI: body mass index; ***ASA***: American Society of Anaesthesiologists; ***MDT*** meeting: multidisciplinary tumour board meeting; ***LAR***: low anterior resection; ***low Hartmann***: LAR with end-colostomy; ***APR***: abdominoperineal resection. ***Different*** surgical procedures included local resection procedures and proctocolectomy.

Table 2. Postoperative outcomes of cT1-3 rectal cancer patients

	Low volume (0-19) N=3210 (21.9%)	Medium volume (20-50) N=8730 (59.6%)	High volume (>50) N=2711 (18.5%)	P value
Pathologic tumour stage				
pT0	198 (6.3%)	576 (6.8%)	139 (5.3%)	
pT1	297 (9.5%)	930 (10.9%)	275 (10.5%)	
pT2	1124 (36.0%)	2811 (33.0%)	893 (34.0%)	
pT3	1446 (46.3%)	3989 (46.9%)	1265 (48.2%)	
pT4	61 (2.0%)	206 (2.4%)	53 (2.0%)	0.007
Pathologic lymph node stage				
pN0	2112 (67.4%)	5471 (65.7%)	1706 (66.0%)	
pN1	727 (23.2%)	1931 (23.2%)	601 (23.3%)	
pN2	293 (9.4%)	927 (11.1%)	276 (10.7%)	0.099
R0 resection	3025 (96.6%)	8063 (96.6%)	2463 (97.0%)	
Irradical resection[a]	107 (3.4%)	283 (3.4%)	77 (3.0%)	0.647
Any complication	1079 (33.8%)	3141 (36.6%)	1018 (38.1%)	0.009
Respiratory complication	116 (4.0%)	349 (4.4%)	110 (4.5%)	0.547
Cardiac complication	81 (2.1%)	217 (2.8%)	66 (2.7%)	0.985
Reintervention[b]	308 (11.5%)	886 (12.6%)	315 (14.8%)	0.002
(re)laparotomy	170 (7.0%)	420 (6.6%)	168 (8.6%)	0.001
Anastomotic leakage	78 (5.4%)	300 (8.1%)	96 (8.6%)	0.001
Other intra-abdominal abscess	59 (2.2%)	141 (2.0%)	55 (2.6%)	0.257
Ileus	44 (1.6%)	117 (1.7%)	22 (1.0%)	0.110
30-day or in-hospital mortality	62 (1.9%)	173 (2.0%)	49 (1.8%)	0.107
Length of stay (d)	8 (IR 7)	8 (IR 7)	7 (IR 8)	<0.001

[a] ***Irradical resection*** includes both R1 and R2 resections (microscopically and macroscopically positive resection margins).
[b] ***Reintervention*** includes both radiologic as surgical reintervention.

volume hospitals, $p < 0.001$). Clinical nodal stage 0 was more frequently seen in low volume hospitals, while synchronous metastasis was less common (Table 3).

An abdominoperineal resection was less frequently performed in low volume hospitals, while laparoscopic resection of cT4 rectal cancer was more common in these centres (52.2% vs. 32.7% and 0.2% in medium and high volume hospitals, respectively, $p < 0.001$). Additional extensive resection of suspected tumour involvement of cT4 rectal cancer was performed in 49.4% in high volume hospitals, as compared to 25.4% in medium volume hospitals and 15.5% in low volume hospitals ($p < 0.001$). Additional resection of metastasis was more frequently performed as well in high volume hospitals (17.5% vs. 14.4% and 3.0% in medium and low volume hospitals, respectively, $p < 0.001$). Intra-operative radiotherapy was used more often as well for cT4 patients in high volume hospitals (Table 3).

Table 3. Baseline and operative characteristics of cT4 rectal cancer patients

	Low volume (0-4) N=759 (50.2%)	Medium volume (5-9) N=336 (22.2%)	High volume (>9) N=416 (27.5%)	P value
Age (y)	67.1±11.0	65.2±12.0	63.3±11.1	<0.001
Male gender	376 (49.5%)	179 (53.3%)	231 (55.5%)	0.126
BMI	25.6±4.6	25.1±4.2	25.2±4.5	0.076
Medical history				
Cardiac	117 (22.8%)	51 (22.0%)	62 (23.8%)	0.885
Vascular	272 (52.7%)	112 (47.7%)	130 (49.8%)	0.290
Pulmonal	97 (18.9%)	43 (18.6%)	43 (16.5%)	0.802
Diabetes	117 (22.8%)	49 (21.2%)	57 (21.9%)	0.889
Neurologic	92 (17.9%)	36 (15.6%)	29 (11.1%)	0.048
ASA class 3 or 4	149 (19.8%)	58 (17.3%)	58 (13.9%)	0.042
MDT meeting preoperative	734 (96.7%)	329 (97.9%)	414 (99.5%)	0.033
Neoadjuvant therapy	674 (89.4%)	294 (88.0%)	349 (84.3%)	0.040
Short-course (5x5 Gy)	127 (17.1%)	52 (15.8%)	31 (7.5%)	
Long-course	43 (5.8%)	23 (7.0%)	31 (7.5%)	
Chemoradiotherapy	494 (66.4%)	214 (65.0%)	285 (69.2%)	<0.001
Tumour characteristics				
cN0	202 (28.8%)	46 (14.5%)	73 (18.0%)	
cN1	278 (39.7%)	83 (26.2%)	135 (33.3%)	
cN2	221 (31.5%)	188 (59.3%)	197 (48.6%)	<0.001
cM1	89 (11.8%)	57 (17.4%)	76 (18.4%)	<0.001
Distance to anal verge (cm)	6.1±4.7	5.7±4.6	6.2±4.6	0.268
Surgical procedures				
LAR	223 (29.4%)	68 (20.3%)	118 (28.4%)	
Low Hartmann	176 (23.2%)	66 (19.7%)	48 (11.5%)	
APR	355 (46.8%)	197 (58.8%)	247 (59.4%)	
Different	5 (0.7%)	4 (1.2%)	3 (0.7%)	<0.001
Laparoscopic	396 (52.2%)	109 (32.7%)	1 (0.2%)	<0.001
Intraoperative radiotherapy	0 (0.0%)	4 (1.4%)	56 (24.9%)	<0.001
Additional resection tumour involvement[a]				<0.001
None	523 (71.0%)	195 (58.2%)	138 (34.0%)	
Limited resection	100 (13.6%)	55 (16.4%)	62 (15.7%)	
Extensive resection	114 (15.5%)	85 (25.4%)	195 (49.4%)	<0.001
Additional resection metastasis	23 (3.0%)	48 (14.4%)	73 (17.5%)	<0.001
Blood transfusion needed	111 (14.8%)	87 (26.6%)	212 (51.0%)	<0.001

BMI: body mass index; ***ASA***: American Society of Anaesthesiologists; ***MDT*** meeting: multidisciplinary tumour board meeting; ***LAR***: low anterior resection; ***low Hartmann***: LAR with end-colostomy; ***APR***: abdominoperineal resection. ***Different*** surgical procedures included local resection procedures and proctocolectomy.

[a] Extensive additional resection of tumour involvement included typically total or partial exenterative procedures, while limited additional resection usually included partial resection of adjacent tissue outside of the mesorectal fascia.

Postoperative outcomes

Pathologic tumour stage 4 was more often found in high volume hospitals (32.6% vs. 21.3% and 25.9% in low and medium hospitals, respectively, $p < 0.001$), while the overall rate of a radical resection did not differ between groups (Table 4). In a sub-analysis of pT4 patients, irradical resections were seen in 33.8% in low volume hospitals, as compared to 22.5% and 20.8% in medium and high volume hospitals ($p = 0.031$).

A complicated course after resection of cT4 rectal cancer occurred in 50.8% in high volume hospitals, as compared to 44.9% in medium volume hospitals and 21.3% in low

Table 4. Postoperative outcomes of cT4 rectal cancer patients

	Low volume (0-4) N=759 (50.2%)	**Medium volume (5-9) N=336 (22.2%)**	**High volume (>9) N=416 (27.5%)**	P value
Pathologic tumour stage				
pT0	66 (9.0%)	24 (7.4%)	35 (8.6%)	
pT1	29 (4.0%)	8 (2.5%)	10 (2.5%)	
pT2	159 (21.7%)	58 (17.9%)	43 (10.6%)	
pT3	323 (44.1%)	150 (46.3%)	185 (45.7%)	
pT4	156 (21.3%)	84 (25.9%)	132 (32.6%)	<0.001
Pathologic lymph node stage				
pN0	480 (65.3%)	196 (60.3%)	936 (64.0%)	
pN1	160 (21.8%)	77 (23.7%)	99 (24.6%)	
pN2	95 (12.9%)	52 (16.0%)	44 (10.9%)	0.243
pM1	94 (13.3%)	57 (18.2%)	76 (19.6%)	0.014
Overall R0 resection	659 (89.1%)	292 (89.3%)	365 (88.4%)	
Overall irradical resection[a]	81 (10.9%)	35 (10.7%)	48 (11.6%)	0.912
pT4 R0 resection	100 (66.2%)	62 (77.5%)	103 (79.2%)	
pT4 irradical resection	51 (33.8%)	18 (22.5%)	27 (20.8%)	0.031
Any complication	294 (38.9%)	151 (44.9%)	211 (50.8%)	0.002
Respiratory complication	42 (6.0%)	10 (3.4%)	32 (8.5%)	0.026
Cardiac complication	12 (1.7%)	10 (3.4%)	15 (4.0%)	0.068
Reintervention[b]	88 (14.1%)	26 (10.5%)	41 (13.4%)	0.364
(re)laparotomy	39 (7.1%)	15 (7.1%)	22 (9.0%)	0.492
Anastomotic leakage	12 (6.6%)	1 (1.9%)	3 (3.2%)	0.258
Other intra-abdominal abscess	31 (5.0%)	7 (2.8%)	14 (4.6%)	0.378
Ileus	10 (1.6%)	4 (1.6%)	1 (0.3%)	0.230
30-day or in-hospital mortality	12 (1.6%)	2 (0.6%)	9 (2.2%)	0.214
Length of stay (d)	8 (IR 8)	9 (IR 8)	10 (IR 8)	<0.001

[a] ***Irradical resection*** includes both R1 and R2 resections (microscopically and macroscopically positive resection margins).

[b] ***Reintervention*** includes both radiologic as surgical reintervention.

volume hospitals (p = 0.002). The 30-day mortality rate was 1.6% in low volume hospitals, 0.6% in medium volume hospitals and 2.2% in high volume hospitals (p = 0.214), and reintervention did not differ significantly between groups as well.

In multivariate analysis, ASA class 3 or 4, extensive resection of tumour involvement, and abdominoperineal resection were associated with increased risks of complications, while female gender was associated with lower risk of complications. Hospital volume did not significantly affect the risk of complications (Table 5).

Table 5. Predictors of a complicated course after resection of cT4 rectal cancer in multivariate analysis

Variable	Odds ratio	95%CI	P value
Female gender	0.60	0.46-0.79	<0.001
Cardiac co-morbidity	1.31	0.95-1.82	0.105
ASA class 3 or 4	1.47	1.07-2.02	0.019
pT4	1.36	0.98-1.88	0.070
Laparoscopic approach	0.92	0.67-1.27	0.598
APR[a]	1.40	1.07-1.84	0.015
Extensive resection of tumour involvement	1.60	1.14-2.26	0.007
Additional resection metastasis	1.31	0.82-2.08	0.253
Hospital volume[b]			
Low volume (0-19)	1.00	-	-
Medium volume (20-50)	1.09	0.77-1.54	0.618
High volume (>51)	1.30	0.89-1.90	0.169

ASA: American Society of Anaesthesiologists.
[a] ***APR***: abdominoperineal resection; low anterior resection or low Hartmann procedure was used as reference category.
[b] Low hospital volume was used as reference category.

DISCUSSION

In this nationwide analysis, perioperative outcomes of cT1-3 rectal cancer surgery were not superior in high volume hospitals as compared to medium or low volume hospitals. With regards to cT4 rectal cancer, high volume hospitals performed more extensive surgical treatment of primary tumour and metastases, with similar perioperative outcomes. In case of pT4 rectal cancer, low volume was associated with increased rates of irradical resection.

Approximately 90% of rectal cancer resections in the Netherlands were performed for cT1-3 tumours, which usually can be treated by standard TME procedures or even local excision in selected cases.(7) Risks of complications, anastomotic leakage, and reintervention were slightly decreased in lower volume hospitals after surgery for cT1-3 rectal cancer, while

the rate of irradical resection and 30-day mortality were similar for the different volume groups. Therefore, it appears that further centralizing the care by increasing the minimal numbers to treat per centre may not be needed for patients without locally advanced disease in case of proper protocols, MDT meetings and regional networks.

In patients with tumour invasion through the mesorectal fascia (cT4), more radical procedures than standard TME surgery is needed in order to achieve R0-resections. These surgical procedures beyond the TME planes are less straightforward and more technically demanding compared to cT1-3 rectal cancer.(8) In addition, the advanced stages of rectal cancer have the greatest benefit of a multimodality treatment, including neoadjuvant chemoradiotherapy, to facilitate complete resections and reduce local recurrence rates.(5, 6) Accurate staging of the rectal tumour by a dedicated MDT is essential to select those patients who should be treated with neoadjuvant therapy, and to assess what kind of surgical approach is needed.

We observed that in high cT4 volume hospitals, patients were more often discussed preoperatively in a MDT meeting and rates of neoadjuvant chemoradiotherapy were higher. It remains unclear why preoperative chemoradiotherapy was less frequently adopted for cT4 rectal cancer in low and medium volume hospitals, possibly this was related to inadequate preoperative staging. Generally, in order to facilitate adequate preoperative staging and optimal neoadjuvant treatment, all rectal cancer patients should be discussed preoperatively in a MDT meeting. Patients in medium or high cT4 volume hospitals underwent more abdominoperineal resections, and additional resection of tumour involvement outside of the mesorectal fascia was more often needed, as compared to low volume hospitals. Intraoperative radiotherapy and resection of metastasis were performed more frequently as well. High volume hospitals performed less laparoscopic cT4 resections, which may suggest more advanced tumour stages in these hospitals. Pathologic examination revealed more frequently pT4 in high volume hospitals, while R0 rates were similar between low, medium and high volume hospitals. In a sub-analysis of pT4 patients, the rate of irradical resection was significantly increased in low volume hospitals (34%). To our knowledge, this is the first study evaluating pathologic outcomes stratified for hospital volume and tumour stage. Gietelink and collagues(14) did show that a low overall hospital volume defined as < 20 rectal cancer resections per year, was associated with a higher risk of CRM involvement, but they did not perform sub-analysis for different tumour stages.(14)

The extensive surgical treatment offered for cT4 rectal cancer in high volume hospitals was associated with increased rates of overall postoperative complications. However, after adjusting for confounding factors in multivariable analysis, including the type of surgery (APR) and extensive additional resection, hospital volume did not significantly affect the

complication rate anymore. Postoperative mortality rates were similar for low, medium and high volume hospitals as well. These findings may suggest that for true cT4 rectal cancer, high volume hospitals may offer a better multimodality treatment, eventually resulting in lower positive resection margins.

Obviously, data regarding overall and local recurrence-free survival, stratified for hospital volume, is needed in order to assess if centralized care for locally advanced rectal cancer translates in a better long-term outcome. Unfortunately, the DSCA registry only contains data regarding perioperative outcomes. Regarding long-term outcomes of colorectal cancer, there appears to be a volume-outcome relationship as suggested in a Cochrane review; however, this was not stratified for tumour stage.(15) Most individual studies suggest similar overall survival rates at 5 years after cT1-4 rectal cancer surgery for low, medium and high volume hospitals.(10, 16-18) Hodgson and colleagues(19) did demonstrate higher survival 2 years after surgery in high volume hospitals (84%) as compared to low volume hospitals (77%), however, their study did not differentiate either between cT1-3 and cT4 rectal cancer. In addition, patients were operated between 1994 and 1997 and neoadjuvant treatment has improved considerably since then.(19)

Since positive circumferential resection margins are associated with increased local recurrence rates and poorer survival in the literature, long-term outcomes of (true) cT4 patients operated in low volume hospitals may be inferior as compared to medium or high cT4 volume hospitals.(3, 4) Future research should investigate whether higher hospital volume does indeed lead to improved survival, in order to confirm if centralized care for locally advanced rectal cancer is warranted.

Large population-based cohort studies, such as the present data from the DSCA, provide proper insights regarding the influence of hospital volume on perioperative outcomes of rectal cancer. However, limitations of the present study design should be taken into account, such as incompleteness of data. The hospital volume was based on the number of cases enrolled, which could theoretically differ from the actual hospital volume. Furthermore, we did not have details regarding exact additional resections performed for tumour involvement. Although registration bias cannot be excluded fully since data are self-reported, recent validation of the DSCA against the Dutch National Cancer Registry showed high accuracy and completeness of the data.(12) In addition, patient of more advanced stages of rectal cancer may have caused some bias in the present evaluation. Finally, long-term outcomes were not available for this evaluation, which are essential for determining whether centralized care is needed for cT1-3 and cT4 rectal cancer.

In conclusion, perioperative outcomes of cT1-3 rectal cancer surgery were not superior in high volume hospitals as compared to medium or low volume hospitals, so there appears no benefit for centralization. With regards to cT4 rectal cancer, high volume hospitals performed more extensive surgical treatment with similar perioperative results. In case of pT4 rectal cancer, low hospital volume was associated with increased rates of irradical resection. For true cT4 rectal cancer, high volume hospitals may offer better multimodality treatment; however, long-term oncologic outcomes of rectal cancer surgery stratified for hospital volume and tumour stage are needed.

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