# Clinical outcomes in bariatric surgery

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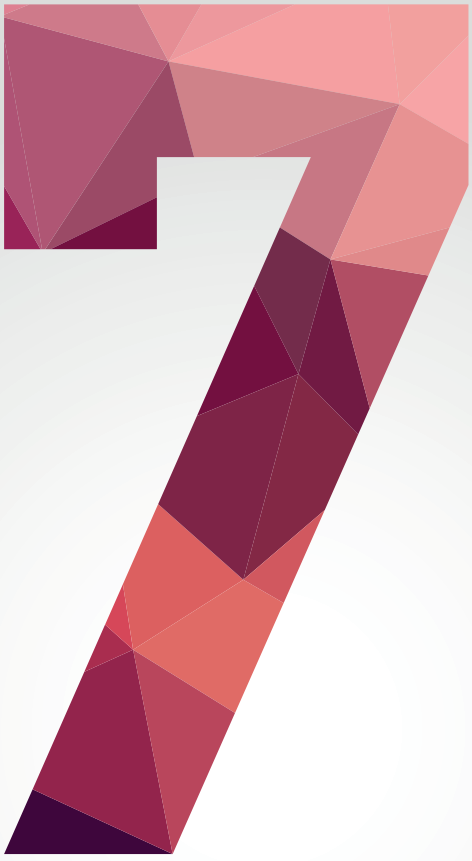

# Obesity as a determinant of perioperative and postoperative outcome in patients following colorectal cancer surgery: A population-based study (2009-2016)

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## ABSTRACT

### BACKGROUND

Obesity is an increasing problem worldwide that can influence perioperative and post-operative outcomes. However, the relationship between obesity and treatment-related perioperative and short-term postoperative morbidity after colorectal resections is still subject to debate.

### STUDY

Patients were selected from the DCRA, a population-based audit including 83 hospitals performing colorectal cancer (CRC) surgery. Data regarding primary resections between 2009 and 2016 were eligible for analyses. Patients were subdivided into six categories: underweight, normal weight, overweight and obesity class I, II and III.

### RESULTS

Of 71,084 patients, 17.7% with colon and 16.4% with rectal cancer were categorized as obese. Significant differences were found for the 30-day overall postoperative complication rate ($p < 0.001$), prolonged hospitalization ($p < 0.001$) and readmission rate (colon cancer $p < 0.005$; rectal cancer $p < 0.002$) in obese CRC patients. Multivariate analysis identified BMI 30 kg/m2 as independent predictor of a complicated postoperative course in CRC patients. Furthermore, obesity-related comorbidities were associated with higher postoperative morbidity, prolonged hospitalization and a higher readmission rate. No significant differences in performance were observed in postoperative outcomes of morbidly obese CRC patients between hospitals performing bariatric surgery and hospitals that did not.

### CONCLUSION

The real-life data analysed in this study reflect daily practice in the Netherlands and identify obesity as a significant risk factor in CRC patients. Obesity-related comorbidities were associated with higher postoperative morbidity, prolonged hospitalization and a higher readmission rate in obese CRC patients. No differences were observed between hospitals performing bariatric surgery and hospitals that did not.

## INTRODUCTION

The World Health Organization (WHO) has recognized obesity as a pandemic disease that contributes to rising healthcare costs worldwide.[1, 2]. Up to one-third of the Western population is currently overweight or obese.[3-5]

Not only is obesity considered to be of growing concern in the aetiology of colorectal cancer (CRC), but there is also a rising awareness of possible treatment-related morbidity and mortality after colorectal resections in obese patients.[6, 7] One study, which included almost 12,000 rectal cancer patients, showed a significant association between obesity and postoperative morbidity.[8] However, findings in the international literature are often contradictive and inconclusive, due to limited study populations.[9, 10]

The aim of this population-based study was to evaluate the influence of obesity on perioperative and short-term postoperative outcomes in patients surgically treated for primary CRC in a nationwide registry. In addition, hospitals performing both bariatric and colorectal surgery and those performing only colorectal surgery were compared to test a possible association between surgical experience with obese patients and the outcomes of these CRC patients.

## MATERIAL AND METHODS

### DATA SOURCE

Data were derived from the Dutch ColoRectal Audit (DCRA), formerly known as the Dutch Surgical Colorectal Audit (DSCA). The DCRA collects information on patients, tumours, treatment, perioperative and short-term outcome characteristics (<30 days) of all patients undergoing surgical resection for primary CRC in the Netherlands.[6]

### PATIENT SELECTION

For this study, no ethical approval or informed consent was required under Dutch law. All patients registered in the DCRA undergoing primary colorectal tumour resection between 1 January 2009 and 31 December 2016, were evaluated. Minimal data requirements were date of birth, body mass index (BMI), date of operation, type of surgery, tumour specifications and 30-day morbidity. All patients were examined preoperatively by an anaesthesiologist no more than 2 working days before the elective operation. Body weight and height were measured by the anaesthetist as standard procedure by all elective operations.

In addition to demographics and the American Society of Anesthesiologists (ASA) classification [11], an extensive set of comorbidities were registered in the DCRA. The Charlson Comorbidity Index (CCI) [12] was used as a composite comorbidity score.[13, 14]

### OUTCOME PARAMETERS

The primary endpoint of this study was a severe adverse postoperative event captured by a composite measure: complicated postoperative course. A complicated postoperative course was defined as prolonged hospitalization (>14 days postoperative) or Clavien-Dindo Classification of Surgical Complications (CD) grade III or higher.[15] It includes complications requiring surgical, endoscopic and/or radiological interventions (CD grade III), life-threatening complications requiring admission to an intensive care unit (CD grade IV) or death (CD grade V).[16]

Secondary endpoints included any perioperative and postoperative complications, defined as a surgical or non-surgical complication occurring within 30 days after the primary resection, not classified as CD grade III or higher. In the DCRA, perioperative complications, postoperative complications, wound infections, wound dehiscence and intra-abdominal complications, such as postoperative bleeding, ileus, infection, abscess or anastomotic leakage, were registered when a re-intervention was performed. Non-surgical complications were defined as cardiac, thromboembolic, pulmonary, infectious, neurological or other.

## STATISTICAL ANALYSIS

Patients were subdivided into different weight categories, as defined by the World Health Organization: underweight (BMI < 18.5 kg/m$^2$), normal weight (BMI 18.5 – 24.9 kg/m$^2$), overweight (BMI 25.0 – 29.9 kg/m$^2$), obesity class I (BMI 29.9 – 34.9 kg/m$^2$), obesity class II (BMI 35.0 – 39.9 kg/m$^2$), obesity class III (BMI ≥ 40.0 kg/m$^2$).[17]

Differences in patient and treatment characteristics for the different weight categories were assessed using Mann-Whitney *U* test for categorical variables and an independent sample t-test for continuous variables. Obese patients (BMI ≥ 30.0 kg/m$^2$) were compared with normal-weight patients (BMI 18.5 – 24.9 kg/m$^2$).

To evaluate hospital outcomes, a multivariate logistic regression was performed. The regression included gender, age, comorbidity-related scores (CCI score, ASA score), tumour location, pathological tumour stage, surgery setting (elective or urgent/emergency), preoperative tumour complications, additional resection due to tumour

invasion or to metastases as single factors. The variable BMI has been left out of the standard case-mix correction.[6]

The risk of postoperative complication was calculated using multivariate logistic regression analysis. Comorbidity-related scores and BMI were entered in the multivariate analysis to evaluate the effects of obesity and its associated comorbidities on postoperative outcome. Next to the p-values calculated with the Mann-Whitney *U* test, are the odds ratios (OR) stated. An OR is a measure of association between an exposure and an outcome.[18]

Comparisons were made between hospitals performing both bariatric and colorectal surgery and those performing only colorectal surgery. Analyses were performed to identify whether obese patients with CRC were more frequently referred to hospitals performing bariatric surgery and if patients were equally distributed (with regard to patient characteristics) among both types of hospitals.

R version 3.4.2 was used for statistical analysis in combination with the "Companion to Applied Regression"- package (car 2.1-5), "A Grammar of Data Manipulation"-package (dplyr 0.7.4), "Data Visualization for Statistics"-package (sjmisc 2.6.2) and "Labelled Data Utility Functions"-package (sjlabelled 1.0.4).

## RESULTS

### BASELINE CHARACTERISTICS

A total of 83 participating hospitals entered 77,819 unique patient records, including 55,892 (71.8%) colon cancer and 21,595 (27.8%) rectal cancer patients. The 332 (0.4%) patients with an unknown tumour, were excluded. In total, 50,876 (91.0%) colon cancer and 20,208 (93.6%) rectal cancer patients for whom a computable preoperative BMI could be calculated, were eligible for final analysis. **Table 1a** and **Table 1b** show the baseline characteristics of CRC patients in the different weight categories, during the study period (2009 – 2016).

### OBESE COLON CANCER (OCC) PATIENTS

Of the 50,876 colon cancer patients, 9016 (17.7%) patients were obese as shown in **Table 1a**. OCC patients were significantly younger (mean 69.4 years; SD ± 9.9, $p < 0.001$) compared with normal-weight colon cancer (NCC) patients (mean 70.5 years; SD ± 11.5, $p < 0.001$) and overweight colon cancer patients (mean 70.6 years; SD ± 10.2, $p < 0.001$) (**Table 1a**).

**Table 1a:** Patient, tumour and treatment characteristics of colon cancer patients combined with postoperative complications. Legend: *Mortality is shown as Clavien-Dindo classification grade V; **Clavien-Dindo classification grade ≥III combined with prolonged hospital stay; red values are column percentage values; green values are row percentage values. Abbreviations: ASA, American Society of Anesthesiologists risk score.

| | | Total | | Normal weight 18.5 – 24.9 kg/m$^2$ | | Overweight 25.0 – 29.9 kg/m$^2$ | | Obesity > 30.0 kg/m$^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N | % | N | % | N | % | N | % | *p*-value |
| **Number of colon cancer patients** | | 50,876 | 100.0 | 20,755 | 40.8 | 20,212 | 39.7 | 9,016 | 17.7 | <0.001 |
| **Patient characteristics** | | | | | | | | | | |
| Gender | Female | 23,759 | 46.7 | 10,690 | 45.0 | 7,987 | 33.6 | 4,431 | 18.6 | <0.001 |
| Age | < 60 years | 7,297 | 14.3 | 3,289 | 45.1 | 2,580 | 35.4 | 1,276 | 17.5 | <0.001 |
| | 60 – 70 years | 15,424 | 30.3 | 5,762 | 37.4 | 6,248 | 40.5 | 3,171 | 20.6 | <0.001 |
| | 70 – 80 years | 17,522 | 34.4 | 6,736 | 38.4 | 7,336 | 41.9 | 3,166 | 18.1 | <0.001 |
| | ≥ 80 years | 10,613 | 20.9 | 4,958 | 46.7 | 4,045 | 38.1 | 1,396 | 13.2 | <0.001 |
| ASA score | I - II | 37,944 | 74.6 | 16,005 | 42.2 | 15,409 | 40.6 | 5,909 | 15.6 | <0.001 |
| | III | 11,898 | 23.4 | 4,307 | 36.2 | 4,445 | 37.4 | 2,904 | 24.4 | <0.001 |
| | IV - V | 897 | 1.8 | 372 | 41.5 | 313 | 34.9 | 184 | 20.5 | <0.001 |
| Charlson score | 1 | 11,755 | 23.1 | 4,323 | 36.8 | 4,721 | 40.2 | 2,558 | 21.8 | <0.001 |
| | ≥2 | 13,692 | 26.9 | 4,721 | 36.5 | 5,535 | 40.4 | 2,901 | 21.2 | <0.001 |
| Body mass index | 18.5 – 24.9 kg/m$^2$ | 20,755 | 40.8 | - | - | - | - | - | - | - |
| | 25.0 – 29.9 kg/m$^2$ | 20,212 | 39.7 | - | - | - | - | - | - | - |
| | 30.0 – 34.9 kg/m$^2$ | 6,881 | 13.5 | - | - | - | - | - | - | - |
| | 35.0 – 39.9 kg/m$^2$ | 1,603 | 3.2 | - | - | - | - | - | - | - |
| | ≥ 40.0 kg/m$^2$ | 532 | 1.0 | - | - | - | - | - | - | - |
| Abdominal surgical history | Yes | 17,590 | 34.6 | 7,131 | 40.5 | 6,727 | 38.2 | 3,423 | 19.5 | <0.001 |
| **Tumour characteristics** | | | | | | | | | | |
| Tumour location | Right colon | 22,272 | 43.8 | 9,461 | 42.5 | 8,553 | 38.4 | 3,795 | 17.0 | <0.001 |
| | Transversum / left colon | 8,584 | 16.9 | 3,487 | 40.6 | 3,421 | 39.9 | 1,502 | 17.5 | 0,191 |

**Table 1a:** Patient, tumour and treatment characteristics of colon cancer patients combined with postoperative complications. Legend: *Mortality is shown as Clavien-Dindo classification grade V; **Clavien-Dindo classification grade ≥III combined with prolonged hospital stay; red values are column percentage values; green values are row percentage values. Abbreviations: ASA, American Society of Anesthesiologists risk score. (continued)

| | | Total | | Normal weight 18.5 – 24.9 kg/m$^2$ | | Overweight 25.0 – 29.9 kg/m$^2$ | | Obesity > 30.0 kg/m$^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N | % | N | % | N | % | N | % | *p*-value |
| | Sigmoid | 20,020 | 39.4 | 7,807 | 39.0 | 8,238 | 41.1 | 3,719 | 18.6 | <0.001 |
| Preoperative tumour complications | Bleeding | 8,159 | 16.0 | 3,274 | 40.1 | 3,302 | 40.5 | 1,454 | 17.8 | 0.284 |
| | Obstruction/ileus | 5,953 | 11.7 | 2,971 | 49.9 | 2,067 | 34.7 | 730 | 12.3 | <0.001 |
| | Abscess | 467 | 0.9 | 209 | 44.8 | 186 | 39.8 | 61 | 13.1 | 0.034 |
| | Other | 2,891 | 5.7 | 1,494 | 46.7 | 1,149 | 35.9 | 461 | 14.4 | <0.001 |
| Pathological T classification | (y)pT0-1 | 4,321 | 8.5 | 1,456 | 33.7 | 1,847 | 42.7 | 983 | 22.7 | <0.001 |
| | (y)pT2 | 8,317 | 16.3 | 3,108 | 37.4 | 3,457 | 41.6 | 1,645 | 19.8 | <0.001 |
| | (y)pT3 | 29,222 | 57.4 | 12,050 | 41.2 | 11,659 | 39.9 | 5,019 | 17.2 | 0.001 |
| | (y)pT4 | 8,208 | 16.1 | 3,826 | 46.6 | 2,926 | 35.6 | 1,214 | 14.8 | 0.001 |
| | (y)pTx/unknown | 808 | 1.6 | 315 | 39.0 | 323 | 40.0 | 155 | 19.2 | 0.635 |
| Pathological N classification | pN0 | 29,304 | 57.6 | 11,707 | 40.0 | 11,693 | 39.9 | 5,386 | 18.4 | <0.001 |
| | pN1 | 12,485 | 24.5 | 5,226 | 41.9 | 4,947 | 39.6 | 2,106 | 16.9 | 0.006 |
| | pN2 | 8,497 | 16.7 | 3,563 | 41.9 | 3,354 | 39.5 | 1,425 | 16.8 | 0.031 |
| | pNx/unknown | 590 | 1.2 | 259 | 43.9 | 218 | 36.9 | 99 | 16.8 | 0.244 |
| Metastatic disease | Yes | 5,962 | 11.7 | 2,773 | 46.5 | 2,189 | 36.7 | 865 | 14.5 | <0.001 |
| Lymph nodes | ≥10 retrieved | 45,351 | 89.1 | 18,514 | 40.8 | 18,036 | 39.8 | 8,010 | 17.7 | 0.169 |
| **Surgical characteristics** | | | | | | | | | | |
| Setting | Urgent | 7,708 | 15.2 | 3,807 | 49.4 | 2,683 | 34.8 | 957 | 12.4 | <0.001 |
| Approach | Laparoscopic | 29,249 | 57.5 | 11,206 | 38.3 | 12,107 | 41.4 | 5,575 | 19.1 | <0.001 |
| Conversion | Yes | 3,749 | 7.4 | 1,205 | 32.1 | 1,498 | 40.0 | 991 | 26.4 | <0.001 |
| **Complications** | | | | | | | | | | |

**Table 1a:** Patient, tumour and treatment characteristics of colon cancer patients combined with postoperative complications. Legend: *Mortality is shown as Clavien-Dindo classification grade V; **Clavien-Dindo classification grade ≥III combined with prolonged hospital stay; red values are column percentage values; green values are row percentage values. Abbreviations: ASA, American Society of Anesthesiologists risk score. (continued)

| | | Total | | Normal weight 18.5 – 24.9 kg/m$^2$ | | Overweight 25.0 – 29.9 kg/m$^2$ | | Obesity > 30.0 kg/m$^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N | % | N | % | N | % | N | % | *p*-value |
| Peroperative complications | Total | 1,312 | 2.6 | 486 | 37.0 | 538 | 41.0 | 268 | 20.4 | 0.011 |
| | Bleeding | 205 | 0.4 | 73 | 35.6 | 80 | 39.0 | 50 | 24.4 | 0.080 |
| | Bowel injury | 351 | 0.7 | 124 | 35.3 | 150 | 42.7 | 69 | 19.7 | 0.196 |
| | Ureter/urethral injury | 89 | 0.2 | 36 | 40.4 | 28 | 31.5 | 22 | 24.7 | 0.112 |
| | Bladder injury | 61 | 0.1 | 23 | 37.7 | 25 | 41.0 | 12 | 19.7 | 0.926 |
| Postoperative complications | Total | 15,173 | 29.8 | 5,898 | 38.9 | 5,995 | 39.5 | 2,984 | 19.7 | <0.001 |
| | Surgical complications | 7,595 | 14.9 | 2,847 | 37.5 | 3,029 | 39.9 | 1,579 | 20.8 | <0.001 |
| | Pulmonary complications | 2,820 | 5.5 | 1,116 | 39.6 | 1,109 | 39.3 | 521 | 18.5 | 0.012 |
| | Cardiac complications | 1,791 | 3.5 | 698 | 39.0 | 684 | 38.2 | 373 | 20.8 | 0.507 |
| | Thromboembolic complications | 341 | 0.7 | 125 | 36.7 | 134 | 39.3 | 76 | 22.3 | 0.631 |
| | Infectious complications | 1,897 | 3.7 | 715 | 37.7 | 752 | 39.6 | 395 | 20.8 | 0.497 |
| | Neurological complications | 727 | 1.4 | 298 | 41.0 | 286 | 39.3 | 122 | 16.8 | 0.056 |
| Postoperative re-interventions | Total | 4,219 | 8.3 | 1,608 | 38.1 | 1,708 | 40.5 | 808 | 19.2 | <0.001 |
| | Anastomotic leakage | 1,935 | 3.8 | 729 | 37.7 | 785 | 40.6 | 381 | 19.7 | 0.014 |
| | Bleeding | 241 | 0.5 | 113 | 46.9 | 90 | 37.3 | 33 | 13.7 | 0.167 |
| Clavien-Dindo classification* | Grade III-IV | 4,402 | 8.7 | 1651 | 37.5 | 1,737 | 39.5 | 923 | 21.0 | <0.001 |
| | Grade V | 1,610 | 3.2 | 669 | 41.6 | 614 | 38.1 | 269 | 16.7 | <0.001 |
| Prolonged hospital stay | >14 days | 8,740 | 17.2 | 3,531 | 40.4 | 3,408 | 39.0 | 1,590 | 18.2 | <0.001 |
| | Duration (mean/days/SD) | 9.4 | ± 8.8 | 9.4 | ± 8.7 | 9.3 | ± 8.8 | 9.7 | ± 9.1 | - |
| Severe complicated course** | Yes | 11,228 | 22.1 | 4,491 | 40.0 | 4,380 | 39.0 | 2,096 | 18.7 | <0.001 |
| Readmission | Yes | 2,604 | 5.1 | 1,000 | 38.4 | 1,032 | 39.6 | 522 | 20.0 | 0.005 |

This group also had a higher ASA-score and were associated with more preoperative comorbidities (OCC 87.3% vs NCC 71.6%, $p < 0.001$). In particular, cardiac, vascular, diabetes, and pulmonary comorbidities were recorded significantly more frequently (**Fig. 1**). Colon tumours were seen significantly more in the right colon and had a significantly lower pathological and clinical tumour stage. OCC patients were mostly operated using a laparoscopic approach (OCC 61.8% [5575 of 9016] versus NCC 54.0% [11,206 of 20,755], $p < 0.001$), but less frequently underwent an emergency procedure (OCC 10.6% [957 of 9016], NCC 18.3% [3807 of 20,755], $p < 0.001$). In 11.0% of OCC and 5.8% of NCC patients, a laparoscopic conversion was needed. Furthermore, more perioperative complications were seen in the OCC group (p ¼ 0.011), but for the specific complications bleeding, bowel injury, ureter/urethral and bladder injury, no significant differences were observed.

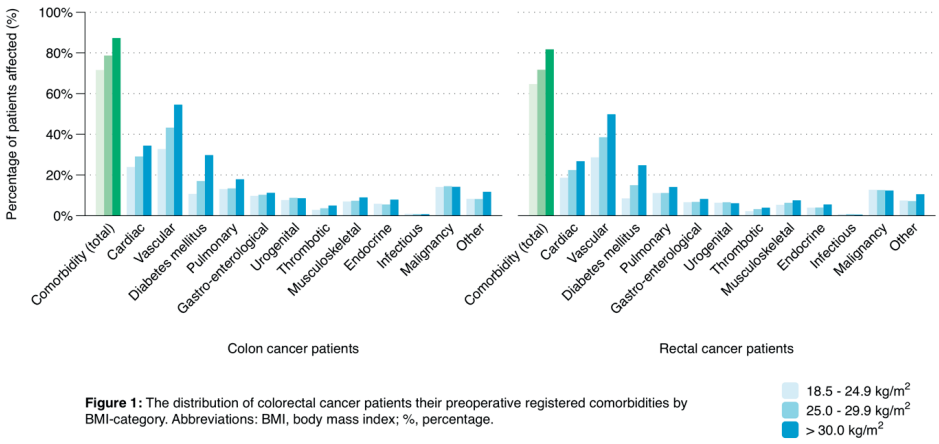


**Figure 1:** The distribution of colorectal cancer patients their preoperative registered comorbidities by BMI-category. Abbreviations: BMI, body mass index; %, percentage.

In total, 33.1% (n = 2984) of the OCC patients developed a postoperative complication compared with 28.4% (n = 5898) of the NCC patients. Significant differences in surgical complications ($p < 0.001$) and pulmonary complications ($p < 0.001$) were seen in the OCC group. Furthermore, significant differences were observed in postoperative re-interventions performed for anastomotic leakage ($p < 0.014$) and for severe complicated course in the OCC group ($p < 0.001$). The higher number of total postoperative and surgical complications in combination with a higher CD grade and prolonged hospitalization resulted in more OCC patients with a severe complicated postoperative course. Regarding the percentage of mortality (CD grade V), a slight but significant difference was seen in favour of the OCC group: 3.0% [269 of 9016] versus 3.2% [669 of 20,755] in the NCC group ($p < 0.001$).

**Table 1b:** Patient, tumour and treatment characteristics of rectal cancer patients combined with postoperative complications. Legend: *Mortality is shown as Clavien-Dindo classification grade V; **Clavien-Dindo classification grade ≥III combined with prolonged hospital stay; red values are column percentage values; green values are row percentage values. Abbreviations: ASA, American Society of Anesthesiologists risk score.

| | | Total | | Normal weight 18.5 – 24.9 kg/m$^2$ | | Overweight 25.0 – 29.9 kg/m$^2$ | | Obesity > 30.0 kg/m$^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N | % | N | % | N | % | N | % | *p*-value |
| **Number of rectal cancer patients** | | 20,208 | 100.0 | 8,186 | 40.5 | 8,377 | 41.5 | 3,322 | 16.4 | <0.001 |
| **Patient characteristics** | | | | | | | | | | |
| Gender | Female | 7,426 | 36.7 | 3,305 | 44.5 | 2,560 | 34.5 | 1,357 | 18.3 | <0.001 |
| Age | < 60 years | 4,429 | 21.9 | 1,903 | 43.0 | 1,725 | 38.9 | 700 | 15.8 | <0.001 |
| | 60 – 70 years | 7,001 | 34.6 | 2,637 | 37.7 | 2,967 | 42.4 | 1,298 | 18.5 | <0.001 |
| | 70 – 80 years | 6,286 | 31.1 | 2,500 | 39.8 | 2,663 | 42.4 | 1,038 | 16.5 | 0.088 |
| | ≥ 80 years | 2,481 | 12.3 | 1,143 | 46.1 | 1,020 | 41.1 | 280 | 11.3 | <0.001 |
| ASA score | I - II | 16,713 | 82.7 | 6,957 | 41.6 | 6,999 | 41.9 | 2,498 | 14.9 | <0.001 |
| | III | 3,274 | 16.2 | 1,132 | 34.6 | 1,290 | 39.4 | 795 | 24.3 | <0.001 |
| | IV - V | 152 | 0.8 | 74 | 48.7 | 51 | 33.6 | 22 | 14.5 | 0.046 |
| Charlson score | 1 | 4,158 | 20.6 | 1,479 | 35.6 | 1,787 | 43.0 | 827 | 19.9 | <0.001 |
| | ≥2 | 4,440 | 22.0 | 1,646 | 37.1 | 1,866 | 42.0 | 857 | 19.3 | <0.001 |
| Body mass index | 18.5 – 24.9 kg/m$^2$ | 8,186 | 40.5 | - | - | - | - | - | - | - |
| | 25.0 – 29.9 kg/m$^2$ | 8,377 | 41.5 | - | - | - | - | - | - | - |
| | 30.0 – 34.9 kg/m$^2$ | 2,684 | 13.3 | - | - | - | - | - | - | - |
| | 35.0 – 39.9 kg/m$^2$ | 488 | 2.4 | - | - | - | - | - | - | - |
| | ≥ 40.0 kg/m$^2$ | 150 | 0.7 | - | - | - | - | - | - | - |
| Abdominal surgical history | Yes | 6,096 | 30.2 | 2,396 | 39.3 | 2,445 | 40.1 | 1,133 | 18.6 | <0.001 |
| **Tumour characteristics** | | | | | | | | | | |
| Distance anal verge | <5 cm | 5,290 | 26.2 | 2,187 | 41.3 | 2,141 | 40.5 | 869 | 16.4 | 0.112 |
| | 5-10 cm | 6,340 | 31.4 | 2,623 | 41.4 | 2,623 | 41.4 | 980 | 15.5 | 0.011 |

**Table 1b:** Patient, tumour and treatment characteristics of rectal cancer patients combined with postoperative complications. Legend: *Mortality is shown as Clavien-Dindo classification grade V; **Clavien-Dindo classification grade ≥III combined with prolonged hospital stay; red values are column percentage values; green values are row percentage values. Abbreviations: ASA, American Society of Anesthesiologists risk score. (continued)

| | | Total | | Normal weight 18.5 – 24.9 kg/m$^2$ | | Overweight 25.0 – 29.9 kg/m$^2$ | | Obesity > 30.0 kg/m$^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N | % | N | % | N | % | N | % | *p*-value |
| | ≥10 cm | 8,040 | 39.8 | 3,126 | 38.9 | 3,433 | 42.7 | 1,380 | 17.2 | <0.001 |
| Preoperative tumour complications | Bleeding | 2,448 | 12.1 | 985 | 40.2 | 997 | 40.7 | 421 | 17.2 | 0.513 |
| | Obstruction/ileus | 572 | 2.8 | 298 | 52.1 | 196 | 34.3 | 54 | 9.4 | <0.001 |
| | Abscess | 107 | 0.5 | 56 | 52.3 | 27 | 25.2 | 18 | 16.8 | <0.001 |
| | Other | 846 | 4.2 | 386 | 45.6 | 342 | 40.4 | 94 | 11.1 | <0.001 |
| Clinical T classification | cT1 | 649 | 3.2 | 242 | 37.3 | 284 | 43.8 | 119 | 18.3 | 0.044 |
| | cT2 | 4,760 | 23.6 | 1,812 | 38.1 | 2,066 | 43.4 | 828 | 17.4 | <0.001 |
| | cT3 | 11,462 | 56.7 | 4,656 | 40.6 | 4,764 | 41.6 | 1,872 | 16.3 | 0.468 |
| | cT4 | 1,923 | 9.5 | 896 | 46.6 | 676 | 35.2 | 279 | 14.5 | <0.001 |
| | cTx/unknown | 1,414 | 7.0 | 580 | 41.0 | 587 | 41.5 | 224 | 15.8 | 0.933 |
| Clinical N classification | cN0 | 8,119 | 40.2 | 3,286 | 40.5 | 3,365 | 41.4 | 1,343 | 16.5 | 0.943 |
| | cN1 | 6,314 | 31.2 | 2,515 | 39.8 | 2,646 | 41.9 | 1,050 | 16.6 | 0.624 |
| | cN2 | 4,059 | 20.1 | 1,660 | 40.9 | 1,655 | 40.8 | 673 | 16.6 | 0.673 |
| | cNx/unknown | 1,716 | 8.5 | 725 | 42.2 | 711 | 41.4 | 256 | 14.9 | 0.212 |
| Pathological T classification | (y)pT0-1 | 1,854 | 9.2 | 712 | 38.4 | 809 | 43.6 | 316 | 17.0 | 0.012 |
| | (y)pT2 | 6,252 | 30.9 | 2,481 | 39.7 | 2,620 | 41.9 | 1,078 | 17.2 | 0.001 |
| | (y)pT3 | 9,389 | 46.5 | 3,814 | 40.6 | 3,883 | 41.4 | 1,534 | 16.3 | 0.805 |
| | (y)pT4 | 944 | 4.7 | 455 | 48.2 | 323 | 34.2 | 126 | 13.3 | <0.001 |
| | (y)pTx/unknown | 1,769 | 8.8 | 724 | 40.9 | 742 | 41.9 | 268 | 15.1 | 0.271 |
| Pathological N classification | pN0 | 12,869 | 63.7 | 5,249 | 40.8 | 5,308 | 41.2 | 2,105 | 16.4 | 0.749 |
| | pN1 | 4,675 | 23.1 | 1,860 | 39.8 | 1,962 | 42.0 | 781 | 16.7 | 0.668 |

**Table 1b:** Patient, tumour and treatment characteristics of rectal cancer patients combined with postoperative complications. Legend: *Mortality is shown as Clavien-Dindo classification grade V; **Clavien-Dindo classification grade ≥III combined with prolonged hospital stay; red values are column percentage values; green values are row percentage values. Abbreviations: ASA, American Society of Anesthesiologists risk score. (continued)

| | | Total | | Normal weight 18.5 – 24.9 kg/m$^2$ | | Overweight 25.0 – 29.9 kg/m$^2$ | | Obesity > 30.0 kg/m$^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N | % | N | % | N | % | N | % | *p*-value |
| | pN2 | 2,325 | 11.5 | 926 | 39.8 | 972 | 41.8 | 391 | 16.8 | 0.885 |
| | pNx/unknown | 339 | 1.7 | 151 | 44.5 | 135 | 39.8 | 45 | 13.3 | 0.175 |
| Metastatic disease | Yes | 1,429 | 7.1 | 657 | 46.0 | 554 | 38.8 | 184 | 12.9 | <0.001 |
| Lymph nodes | ≥10 retrieved | 15,619 | 77.3 | 6,262 | 40.1 | 6,482 | 41.5 | 2,632 | 16.9 | 0.025 |
| **Surgical characteristics** | | | | | | | | | | |
| Setting | Urgent | 294 | 1.5 | 139 | 47.3 | 108 | 36.7 | 34 | 11.6 | 0.002 |
| Approach | Laparoscopic | 12,796 | 63.3 | 5,150 | 40.2 | 5,385 | 42.1 | 2,105 | 16.5 | <0.001 |
| Conversion | Yes | 1,323 | 6.5 | 341 | 25.8 | 602 | 45.5 | 372 | 28.1 | <0.001 |
| **Complications** | | | | | | | | | | |
| Peroperative complications | Total | 783 | 3.9 | 262 | 33.5 | 338 | 43.2 | 169 | 21.6 | <0.001 |
| | Bleeding | 149 | 0.7 | 59 | 39.6 | 57 | 38.3 | 30 | 20.1 | 0.538 |
| | Bowel injury | 142 | 0.7 | 53 | 37.3 | 62 | 43.7 | 23 | 16.2 | 0.515 |
| | Ureter/urethral injury | 123 | 0.6 | 45 | 36.6 | 43 | 35.0 | 32 | 26.0 | 0.021 |
| | Bladder injury | 46 | 0.2 | 14 | 30.4 | 22 | 47.8 | 8 | 17.4 | 0.190 |
| Postoperative complications | Total | 7,604 | 37.6 | 2,874 | 37.8 | 3,159 | 41.5 | 1,452 | 19.1 | <0.001 |
| | Surgical complications | 3,953 | 19.6 | 1,419 | 38.9 | 1,509 | 41.3 | 668 | 18.3 | 0.195 |
| | Pulmonary complications | 855 | 4.2 | 341 | 39.9 | 334 | 39.1 | 159 | 18.6 | 0.056 |
| | Cardiac complications | 540 | 2.7 | 204 | 37.8 | 211 | 39.1 | 117 | 21.7 | 0.409 |
| | Thromboembolic complications | 109 | 0.5 | 41 | 37.6 | 47 | 43.1 | 20 | 18.3 | 0.994 |
| | Infectious complications | 982 | 4.9 | 353 | 35.9 | 390 | 39.7 | 220 | 22.4 | 0.025 |
| | Neurological complications | 241 | 1.2 | 84 | 34.9 | 109 | 45.2 | 43 | 17.8 | 0.530 |

**Table 1b:** Patient, tumour and treatment characteristics of rectal cancer patients combined with postoperative complications. Legend: *Mortality is shown as Clavien-Dindo classification grade V; **Clavien-Dindo classification grade ≥III combined with prolonged hospital stay; red values are column percentage values; green values are row percentage values. Abbreviations: ASA, American Society of Anesthesiologists risk score. (continued)

| | | Total | | Normal weight 18.5 – 24.9 kg/m$^2$ | | Overweight 25.0 – 29.9 kg/m$^2$ | | Obesity > 30.0 kg/m$^2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N | % | N | % | N | % | N | % | *p*-value |
| Postoperative re-interventions | Total | 2,162 | 10.7 | 847 | 39.2 | 896 | 41.4 | 386 | 17.9 | 0.252 |
| | Anastomotic leakage | 723 | 3.6 | 283 | 39.1 | 325 | 45.0 | 109 | 15.1 | 0.103 |
| | Bleeding | 99 | 0.5 | 41 | 41.4 | 40 | 40.4 | 17 | 17.2 | 0.990 |
| Clavien-Dindo classification* | Grade III-IV | 1,995 | 9.9 | 714 | 35.8 | 820 | 41.1 | 424 | 21.3 | <0.001 |
| | Grade V | 386 | 1.9 | 180 | 46.6 | 127 | 32.9 | 66 | 17.1 | <0.001 |
| Prolonged hospital stay | >14 days | 4,423 | 21.9 | 1,683 | 38.1 | 1,799 | 40.7 | 854 | 19.3 | <0.001 |
| | Duration | 11.0 | ± 9.7 | 10.6 | ± 9.6 | 10.9 | ± 9.6 | 11.9 | ± 10.3 | - |
| Severe complicated course** | Yes | 5,509 | 27.3 | 2,087 | 37.9 | 2,242 | 40.7 | 1,080 | 19.6 | <0.001 |
| Readmission | Yes | 1,963 | 9.7 | 746 | 38.0 | 812 | 41.4 | 379 | 19.3 | 0.002 |

Univariate analysis (**Table 2a**) showed a significantly increased risk of postoperative complications in each weight group compared with the NCC group. In particular, an increased risk of postoperative complications was found in class III (BMI ≥ 40.0 kg/m$^2$) OCC patients with an OR of 1.50 (95% confidence interval [CI] 1.26 – 1.78). This relationship remained statistically significant in class III OCC patients (BMI ≥ 40.0 kg/m$^2$) using a multivariate analysis. Factors such as gender, age, tumour location, tumour staging, urgency of operation, preoperative tumour complications, CCI and ASA were entered in the multivariate analysis (**Table 2a**).

## OBESE RECTAL CANCER (ORC) PATIENTS

Of the 20,208 rectal cancer patients, 3322 (16.4%) patients were obese as shown in **Table 1b**. ORC patients were significantly younger (mean 66.7 years; SD ± 9.8) ($p < 0.001$) and had higher ASA and CCI scores compared with normal-weight rectal cancer (NRC) patients (mean 67.1 years; SD ± 11.4) (**Table 1b**).

**Fig. 1** shows the distribution of comorbidities in the ORC group. ORC patients were associated with more preoperative comorbidities (ORC 81.7% vs NRC 64.7%, $p < 0.001$). Looking at tumour characteristics, the ORC patients were diagnosed with a higher located rectal tumour of >10 cm from the anal verge (ORC 41.5% [1380 of 3322] vs NRC 38.2% [3126 of 8186], $p < 0.001$), and had more preoperative tumour complications: obstruction/ileus ($p < 0.001$) and abscesses ($p < 0.001$). Significant differences in pathological and clinical tumour stage were seen: more cT2 ($p < 0.001$) and cT4 tumours ($p < 0.001$) and (y)pT2 ($p < 0.001$) and (y)pT4 tumours ($p < 0.001$). For surgical characteristics, ORC patients were mostly operated using a laparoscopic approach (ORC 63.4% [2105 of 3322] versus NRC 62.9% [5150 of 8186]). Also, in ORC patients (11.2%) more laparoscopic conversion was needed compared to NRC patients (4.2%). On the other hand, the ORC group less frequently underwent an emergency procedure (ORC 1.0% [34 of 3322]; NRC 1.7% [139 of 8186], $p < 0.001$). Furthermore, more perioperative complications were seen in the ORC group ($p < 0.001$), but for the specific complications bleeding, bowel injury, ureter/urethral and bladder injury, no significant differences were observed, in contrast to the NRC patients.

Of all the ORC patients, 43.7% (n = 1452 of 3322) developed a postoperative complication. This was significantly higher in ORC compared with NRC patients (35.1%; n = 2874 of 8186). The ORC group developed more postoperative surgical complications ($p = 0.195$), and a significant difference in infectious complications ($p = 0.025$) was seen. Furthermore, no significant difference was observed in postoperative re-interventions performed for anastomotic leakage ($p = 0.103$) and bleeding ($p = 0.988$) in the ORC group, but a significant difference was seen for a severe complicated course ($p < 0.001$).

The increased postoperative complication rate and the higher CD grade in combination with a significantly prolonged hospitalization for the ORC group resulted in more ORC patients with a prolonged hospital stay (ORC 32.5% vs NRC 25.5%).

Univariate analysis (**Table 2b**) showed a significantly increased risk of postoperative complications in each weight group compared with the NRC group. In particular, an increased risk of postoperative complications was found in class II ORC patients with an OR of 1.92 (95% CI 1.60e2.31), remaining significant in the multivariate analysis (standard) (OR 1.96; CI 1.62e2.39).

The same comorbidity-associated factors, as mentioned for the colon cancer patient group, were entered in the multivariate analysis (**Table 2b**).

### HOSPITALS PERFORMING AND THOSE NOT PERFORMING BARIATRIC SURGERY

There was a wide variation between hospitals in the number of obese CRC patients treated during the study period. Colon cancer patients were treated in 83 individual hospitals with a range of 49 – 1600 surgical procedures per hospital between 2009 and 2016. This was between 11 and 346 per hospital for OCC patients, with a total of 9016 procedures (**Fig. 2**). All 19 hospitals performing bariatric surgery treated a lower total volume (29.6%) of OCC patients compared with hospitals that do not perform bariatric surgery (2668 vs 6,348, respectively). Besides the number of treated patients, there were no statistically significant differences in preoperative characteristics and postoperative outcomes in OCC patients treated in hospitals offering bariatric surgery and those that do not offer bariatric procedures ($p = 0.754$).

Similar results were seen for rectal cancer patients. The 83 hospitals were jointly responsible for 3322 surgical procedures (range 2 – 132 per hospital) for ORC patients. Fig. 2 shows the distribution in volume and the number of complicated postoperative courses. The 19 hospitals performing bariatric surgery were responsible for 1004 surgical procedures for ORC patients (range 6 – 132 per hospital, 30.2%). No significant difference was seen between treatment in hospitals offering bariatric surgery and hospitals that did not with regard to a complicated postoperative course ($p = 0.149$).

**Table 2b:** Univariate and multivariate analyses of rectal cancer patients for a complicated postoperative course. *Multivariate analysis was calculated with CCI-score and ASA-score. Abbreviations: N, number; SD, standard deviation; CI, confidence interval; OR, odds ratio; BMI, body mass index; CCI, Charlson Comorbidity Index; ASA, American Society of Anesthesiologists risk score.

| | **Normal postoperative course** | | **Complicated postoperative course** | | | | |
|---|---|---|---|---|---|---|---|
| | **N** | **%** | **N** | **%** | ***p-value*** | **Odds ratio** | **95% CI** |
| **Rectal cancer patients** | 11,225 | 55.5 | 8,983 | 44.5 | - | - | - |
| **Univariate analysis** | | | | | | | |
| BMI (mean, kg/m$^2$, SD) | 26.0 | ± 4.1 | 26.5 | ± 4.4 | <0.001 | - | - |
| 18.5 – 24.9 kg/m$^2$ | 4,780 | 23.7 | 3,406 | 16.9 | <0.001 | REF | REF |
| 25.0 – 29.9 kg/m$^2$ | 4,643 | 23.0 | 3,734 | 18.5 | 0.780 | **1.13** | **1.06 – 1.20** |
| 30.0 – 34.9 kg/m$^2$ | 1,350 | 6.7 | 1,334 | 6.6 | <0.001 | **1.39** | **1.27 – 1.51** |
| 35.0 – 39.9 kg/m$^2$ | 206 | 1.0 | 282 | 1.4 | <0.001 | **1.92** | **1.60 – 2.31** |
| ≥ 40 kg/m$^2$ | 69 | 0.3 | 81 | 0.4 | 0.023 | **1.65** | **1.19 – 2.45** |
| Comorbidities | 7,608 | 37.6 | 6,624 | 32.8 | <0.001 | **1.33** | **1.26 – 1.42** |
| Cardiac | 2,115 | 10.5 | 2,217 | 11.0 | <0.001 | **1.41** | **1.32 – 1.51** |
| Vascular | 3,839 | 19.0 | 3,459 | 17.1 | <0.001 | **1.20** | **1.14 – 1.28** |
| Diabetes mellitus | 1,416 | 7.0 | 1,373 | 6.8 | <0.001 | **1.25** | **1.15 – 1.35** |
| Pulmonary | 1,156 | 5.7 | 1,220 | 6.0 | <0.001 | **1.37** | **1.26 – 1.49** |
| Gastro-enterological | 721 | 3.6 | 690 | 3.4 | 0.001 | **1.21** | **1.09 – 1.35** |
| Urogenital | 615 | 3.0 | 676 | 3.3 | <0.001 | **1.40** | **1.25 – 1.57** |
| Thrombotic | 284 | 1.4 | 304 | 1.5 | <0.001 | **1.35** | **1.15 – 1.59** |
| Musculoskeletal | 662 | 3.3 | 572 | 2.8 | 0.175 | 1.09 | 0.97 – 1.22 |
| Endocrine | 478 | 2.4 | 370 | 1.8 | 0.648 | 0.97 | 0.84 – 1.11 |
| Infectious | 73 | 0.4 | 75 | 0.4 | 0.148 | 1.29 | 0.93 – 1.78 |
| Malignancy | 1,332 | 6.6 | 1,226 | 6.1 | <0.001 | **1.17** | **1.08 – 1.28** |
| Other | 817 | 4.0 | 772 | 3.8 | 0.001 | **1.20** | **1.08 – 1.33** |
| **Multivariate analysis*** | | | | | | | |
| BMI (mean, kg/m$^2$, SD) | 26.0 | ± 4.1 | 26.5 | ± 4.4 | <0.001 | - | - |
| 18.5 – 24.9 kg/m$^2$ | 4,780 | 23.7 | 3,406 | 16.9 | <0.001 | REF | REF |
| 25.0 – 29.9 kg/m$^2$ | 4,643 | 23.0 | 3,734 | 18.5 | 0.780 | **1.11** | **1.04 – 1.18** |
| 30.0 – 34.9 kg/m$^2$ | 1,350 | 6.7 | 1,334 | 6.6 | <0.001 | **1.39** | **1.26 – 1.52** |
| 35.0 – 39.9 kg/m$^2$ | 206 | 1.0 | 282 | 1.4 | <0.001 | **1.96** | **1.62 – 2.39** |
| ≥ 40 kg/m$^2$ | 69 | 0.3 | 81 | 0.4 | 0.023 | **1.72** | **1.23 – 2.42** |

**Table 2a:** Univariate and multivariate analyses of colon cancer patients for a complicated postoperative course. *Multivariate analysis was calculated with CCI-score and ASA-score. Abbreviations: N, number; SD, standard deviation; CI, confidence interval; OR, odds ratio; BMI, body mass index; CCI, Charlson Comorbidity Index; ASA, American Society of Anesthesiologists risk score.

| | Normal postoperative course | | Complicated postoperative course | | | | |
|---|---|---|---|---|---|---|---|
| | **N** | **%** | **N** | **%** | ***p-value*** | **OR** | **95% CI** |
| **Colon cancer patients** | 33,005 | 64.9 | 17,871 | 35.1 | - | - | - |
| **Univariate analysis** | | | | | | | |
| BMI (mean, kg/m$^2$, SD) | 26.2 | ± 4.4 | 26.5 | ± 4.7 | <0.001 | - | - |
| 18.5 – 24.9 kg/m$^2$ | 13,724 | 27.0 | 7,031 | 13.8 | <0.001 | REF | REF |
| 25.0 – 29.9 kg/m$^2$ | 13,168 | 25.9 | 7,044 | 13.8 | 0.294 | **1.04** | **1.00 – 1.09** |
| 30.0 – 34.9 kg/m$^2$ | 4,311 | 8.5 | 2,570 | 5.1 | <0.001 | **1.16** | **1.10 – 1.23** |
| 35.0 – 39.9 kg/m$^2$ | 964 | 1.9 | 639 | 1.3 | <0.001 | **1.30** | **1.17 – 1.44** |
| ≥ 40 kg/m$^2$ | 301 | 0.6 | 231 | 0.5 | <0.001 | **1.50** | **1.26 – 1.78** |
| Comorbidities | 24,487 | 48.1 | 14,782 | 29.1 | <0.001 | **1.66** | **1.59 – 1.74** |
| Cardiac | 8,111 | 15.9 | 5,986 | 11.8 | <0.001 | **1.55** | **1.49 – 1.61** |
| Vascular | 12,769 | 25.1 | 7,916 | 15.6 | <0.001 | **1.26** | **1.21 – 1.31** |
| Diabetes mellitus | 5,055 | 9.9 | 3,338 | 6.6 | <0.001 | **1.27** | **1.21 – 1.33** |
| Pulmonary | 4,013 | 7.9 | 3,190 | 6.3 | <0.001 | **1.57** | **1.49 – 1.65** |
| Gastro-enterological | 3,058 | 6.0 | 2,161 | 4.2 | <0.001 | **1.35** | **1.27 – 1.43** |
| Urogenital | 2,409 | 4.7 | 1,788 | 3.5 | <0.001 | **1.41** | **1.32 – 1.51** |
| Thrombotic | 1,040 | 2.0 | 758 | 1.5 | <0.001 | **1.36** | **1.24 – 1.50** |
| Musculoskeletal | 2,337 | 4.6 | 1,473 | 2.9 | <0.001 | **1.18** | **1.10 – 1.26** |
| Endocrine | 1,966 | 3.9 | 1,121 | 2.2 | 0.160 | 1.06 | 0.98 – 1.14 |
| Infectious | 269 | 0.5 | 169 | 0.3 | 0.141 | 1.16 | 0.96 – 1.41 |
| Malignancy | 4,249 | 8.4 | 3,022 | 5.9 | <0.001 | **1.38** | **1.31 – 1.45** |
| Other | 2,714 | 5.3 | 1,811 | 3.6 | <0.001 | **1.26** | **1.18 – 1.34** |
| **Multivariate analysis*** | | | | | | | |
| BMI (mean, kg/m$^2$, SD) | 26.2 | ± 4.4 | 26.5 | ± 4.7 | <0.001 | - | - |
| 18.5 – 25.0 kg/m$^2$ | 13,724 | 27.0 | 7,031 | 13.8 | <0.001 | REF | REF |
| 25.0 – 30.0 kg/m$^2$ | 13,168 | 25.9 | 7,044 | 13.8 | 0.294 | **1.07** | **1.02 – 1.11** |
| 30.0 – 35.0 kg/m$^2$ | 4,311 | 8.5 | 2,570 | 5.1 | <0.001 | **1.21** | **1.14 – 1.28** |
| 35.0 – 40.0 kg/m$^2$ | 964 | 1.9 | 639 | 1.3 | <0.001 | **1.38** | **1.24 – 1.54** |
| ≥ 40 kg/m$^2$ | 301 | 0.6 | 231 | 0.5 | <0.001 | **1.50** | **1.25 – 1.79** |

## DISCUSSION

This population-based study on the influence of obesity on perioperative and post-operative outcome in patients during and after CRC resection gives a comprehensive overview of the perioperative and short-term postoperative outcomes of colorectal surgery in obese CRC patients.

Independent analyses and a multivariate logistic regression model, including all obesity-related comorbidities, showed a significantly increased risk factor (OR) in developing a complicated postoperative course for obese CRC patients. This study suggests that obesity and the comorbidities associated with obesity are associated with a higher risk of adverse clinical postoperative outcome, prolonged hospitalization and a higher readmission rate.

Obesity is seen as a potential risk factor for postoperative morbidity, but conflicting results are described in the international literature.[9, 19] A study by Amri et al. showed no significant association between obesity and complications after colon cancer surgery.[10] Our study, however, confirms the results described in the STARSurg Collaborative study and offers additional perioperative and short-term postoperative information of all CRC hospitals in the Netherlands. Including all Dutch academic, teaching and non-teaching hospitals.[6] These results are supported by the findings of Smith et al. which showed a significant association between obesity and postoperative complications after rectal cancer resection in a population of almost 12,000 rectal cancer patients.[8] Also, a recent large, international, multicentre, prospective, cohort study, discussing BMI and postoperative complications after gastrointestinal surgery showed an increased risk of major postoperative complications in overweight and obese patients compared with normal-weight patients.[20]

Furthermore, various scientific articles suggest a so-called "obesity paradox" for pre-obese and mildly obese surgical patients.[2, 21, 22] However, this clinical finding is still a point of discussion and such a paradox was not found in this large population-based study.[23, 24]

Obese CRC patients were generally operated using an open approach, but the literature describes laparoscopic CRC surgery as feasible and safe.[25] In the Netherlands, obese CRC patients are mostly operated laparoscopically. Findings in the international literature confirm the association of obese CRC patients with more emergency procedures and laparoscopic conversions.[26] Also, significantly more postoperative re-interventions were performed for anastomotic leakage in the OCC group, which was described as an

essential determining factor in a recent observational study.[27] Several hypotheses are described in the international literature as a reason for the higher anastomotic leakage rate in the OCC group, e.g. impaired anastomotic microcirculation due to increased abdominal pressure.

As obesity is on the increase, evaluation of care processes in best performing hospitals is of great interest.[28] Although, in our study, the experience in the treatment of obese patients, reflected by hospitals offering bariatric surgery, did not result in better postoperative outcomes. Moreover, because participation in the DCRA is mandatory for Dutch hospitals, it was possible to explore hypotheses regarding the underlying mechanisms explaining the observed variation in outcome of obese patients between hospitals. For example, hospitals performing bariatric surgery could have had more experience in the (surgical) treatment of, as well as perioperative care for, obese patients. Although, the analyses did not show different results for CRC surgery between hospitals performing and hospitals not performing bariatric surgery. More in-depth studies are needed to reveal differences in the care processes that lead to better or worse outcomes for obese patients undergoing CRC resection.

The strength of this study was the advantage of population-based data, which reflect daily general practice in the Netherlands. However, some limitations of this population-based study need to be addressed. The combination of the primary inclusion criteria and missing data caused exclusion of 5016 (9.0%) colon cancer and 1387 (6.4%) rectal cancer patients. External third-party data verification showed that weight and height are not typically missing data in patients with an unfavourable postoperative outcome.[6] Therefore, it can be assumed that the missing data occurred randomly.

Furthermore, the DCRA only provides short-term postoperative surgical and oncological outcomes (<30 days). The content of the DCRA is not only based on mandatory indicators, but also on a dynamic process led by a multidisciplinary team, including colorectal surgeons, oncologists and pathologists, which can lead to new registration of topics based on the team's increasing insights. Information on, e.g. ERAS (enhanced recovery after surgery) and fast-track protocols is currently not registered in the DCRA, but may be added over time. The quality of reported data in the DCRA was influenced over time due to better registration and training of the registrars.[6] In addition, the start of the national colorectal screening programme in 2014, could have influenced the study results.

The effect of disease-related weight loss was difficult to evaluate. Weight and height of the patient were registered on the day of admission, which was no more than two

working days before the colorectal resection. However, significant weight loss before the primary colorectal resection could be expected due to the disease itself, which is known to be associated with worsened postoperative outcomes.[29]

We also took bariatric surgery as a proxy for experience in the surgical treatment of obese patients. The development of more specialized hospitals for optimized care, already showed improvement in several quality outcomes, due to increased operative volumes and more specialized care.[30-32] Surgeons experienced in both bariatric surgery and colorectal surgery might have a better postoperative outcome for (severely) obese patients.[33] It could, therefore, be expected that hospitals performing bariatric surgery could have better results for this specific patient category. However, this study did not find a relationship between experience in the field of bariatric surgery and a favourable postoperative outcome. The assumption in this article, that colorectal surgeons in hospitals offering bariatric surgery by definition have a better experience with obese patients was not sufficient.

## CONCLUSIONS

Using real-life data reflecting daily practice in the Netherlands, we identified obesity as an important risk factor in the care process of CRC patients. Obesity-related comorbidities were associated with higher postoperative morbidity, prolonged hospitalization and a higher readmission rate in obese CRC patients. No differences were observed between hospitals performing bariatric surgery and hospitals that did not.

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