

# Effect of low-level creatinine clearance on short-term postoperative complications in patients with colorectal cancer

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**Background:** Renal function is closely related to cancer prognosis. Since preoperative renal insufficiency has been identified as a risk factor for postoperative complications, this study aimed to investigate the effect of preoperative creatinine clearance rate (CrCl) on short-term prognosis of patients undergoing colorectal surgery.

**Methods:** A retrospective analysis was conducted of the electronic health records of 526 adult patients who underwent elective colorectal cancer (CRC) surgery from September 2014 to February 2019 at the First Affiliated Hospital of Wenzhou Medical University. Cases were divided into two groups according to CrCl level and clinical variables were compared. Risk factors associated with postoperative complications were evaluated through univariate and multivariate logistic regression analyses.

**Results:** A total of 526 patients met the inclusion criteria. The overall rate of postoperative complications was 28.14%. Overall, the incidence of postoperative complications was significantly higher in the low CrCl patients. A low-level CrCl, multi-organ combined resection, and Charlson comorbidity index (CCI) were independent risk factors for short-term complications in patients with CRC. However, a low CrCl was identified as an independent risk factor for short-term postoperative complications in elderly, but not young patients in a subgroup analysis.

**Conclusions:** Preoperative low-level CrCl, multi-organ combined resection, and CCI were significant risk factors of postoperative complications in CRC patients. Preoperative low-level CrCl and multi-organ combined resection has a poor prognostic impact for elderly patients with CRC. These findings should have important implications for health care decision-making among patients with CRC who are at higher risk for post-operative complications.

Keywords: Outcomes; malignant tumor; renal function; hospitalization cost

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#### Introduction

#### Background

Colorectal cancer (CRC) is a common malignancy, with a prevalence putting it as the third most often occurring cancer and the second leading cause of mortality for cancer, accounting for 10.0% and 9.4% of cases, respectively (1). Additionally, it ranks within the top five tumors of mortality and incidence rates in China, indicating a persistent pattern of expansion (2). Surgical resection continues to be a primary therapeutic approach for CRC (3,4); nevertheless, the incidence of postoperative complications poses a significant challenge. Research findings have indicated that the incidence of postoperative complications in CRC ranges from 18% to 38% (5). Thus, it is necessary to analyze the risk factors for postoperative complications among CRC patients.

The phenomenon of aging population in China will result in a growing number of older individuals requiring medical care. The majority of older individuals exhibit a range of comorbidities, including pulmonary or cardiovascular conditions, which have been linked to unfavorable outcomes (6,7). On the contrary, the prognosis for older cancer patients is frequently determined by their physical state (8). Therefore, more attention should be paid to postoperative complications in elderly patients, particularly as they influence preoperative treatment and decision-making.

Preoperative renal insufficiency is significantly

#### Highlight box

#### Key findings

 Preoperative low-level creatinine clearance rate (CrCl) and multiorgan combined resection has a poor prognostic impact for colorectal cancer (CRC) elderly patients.

#### What is known and what is new?

- Multi-organ combined resection and Charlson comorbidity index are risk factors of postoperative complications in CRC patients.
- Preoperative low-level CrCl was identified as another significant risk factor of postoperative complications in CRC patients.

#### What is the implication, and what should change now?

• It is necessary to check, adjust, and stabilize the patient's renal function preoperatively and provide more comprehensive postoperative monitoring for patients requiring combined resection to reduce the occurrence and development of postoperative complications, especially for elderly patients aged >60 years.

associated with postoperative complications and may be underestimated (9). The estimation of glomerular filtration rate (GFR) can serve as an effective method for assessing preoperative renal function. Inulin renal clearance is the recognized gold standard for GFR determination (10), but inulin is expensive, the test requires continuous intravenous infusion of inulin, and the indenture catheter, which is cumbersome to perform and determine. Estimated glomerular filtration rate (eGFR) is currently used as a common indicator to assess kidney function. However, despite being calculated using multiple formulas, each formula has its limitations in different populations. Creatinine clearance rate (CrCl) is another renal function indicator that can reduce the impact of body weight and age on prognosis. It provides a rough estimate of the number of functioning renal units and serves as a quantitative measure of kidney damage. Therefore, this prompts the consideration of serum CrCl as a viable alternative. This approach is popular owing to its expediency and simplicity, in contrast to the laborious process (11). Chronic renal insufficiency before surgery increases the risk of postoperative complications, according to research on adults with gastric cancer (12). We hypothesized that postoperative complications would be more common in CRC patients who had preoperative renal insufficiency. We thus sought to investigate the impact of CrCl on the short-term complication of CRC patients following surgery. Therefore, we aimed to characterize the association of preoperative levels of CrCl on the short-term postoperative complications of patients with CRC. We propose measures to minimize the risk of postoperative complications among this growing patient population. We present this article in accordance with the STROBE reporting checklist (available at https://jgo.amegroups.com/article/view/10.21037/jgo-23-811/rc).

#### **Methods**

#### Patients

From September 2014 to February 2019, we recruited 543 CRC patients at the Gastrointestinal Surgical Department at the First Affiliated Hospital of Wenzhou Medical University. The patients included in the study met the following criteria: (I) definitive diagnosis of CRC; (II) need for CRC surgical resection without receiving neoadjuvant chemotherapy or radiotherapy; (III) measurements of blood and biochemical indicators performed preoperatively and

within 7 days postoperatively; (IV) no relevant renal surgery in the preceding 3 weeks. A total of 17 patients were later excluded because of the following criteria: (I) preoperative chemotherapy or radiotherapy; (II) palliative surgery; (III) emergency surgery. Finally, a total of 526 patients were included in the analysis. All the operations were performed by chief surgeons, each of whom had worked on over 50 CRC cases. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The retrospective study protocol was approved by the Ethics Committee of the First Affiliated Hospital of Wenzhou Medical University (2015-No.023) and individual consent for this retrospective analysis was waived.

#### Data sources

Pre-operative variables collected included patient clinicopathological characteristics such as age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) grade, preoperative nutritional risk score [assessed within 24 h after admission using Nutritional Risk Screening (NRS) 2002 (13)], preoperative plasma albumin concentration (hypoalbuminemia defined as plasma albumin concentration <30 g/L), hemoglobin concentration (anemia defined as hemoglobin concentration <120 g/L for males and <110 g/L for females), neutrophil-to-lymphocyte ratio (NLR), preoperative comorbidity [calculated using Charlson comorbidity index (CCI) score], previous abdominal surgery history, smoking status, alcohol consumption status, disease stage according to the 8th edition of the American Joint Committee on Cancer (AJCC) [tumor-node-metastasis (TNM)] classifications (14), preoperative biochemical indicators including serum calcium (hypocalcemia defined as serum calcium <2.25 mmol/L), serum potassium (hypokalemia defined as serum potassium <3.5 mmol/L), serum sodium (hyponatremia defined as serum sodium <135 mmol/L), serum chloride (hypochloremia defined as serum chloride <96 mmol/L), and serum creatinine. Variables collected of intra-operation details included tumor location (rectum or colon), operative type (although laparoscopic surgery was recommended to all patients, some chose open surgery because of previous abdominal surgery or could not consent to laparoscopic surgery for financial reasons), epidural anesthesia, combined resection, and operative time. Post-operative short-term outcomes were also collected, including complications within 30 days postoperatively, postoperative biochemical indicators (including serum calcium, serum potassium, serum sodium,

serum chlorine), length of stay, and hospitalization costs (cost analysis was conducted in Chinese Yuan).

According to the Clavien-Dindo classification (15), a postoperative complication was defined as a complication of grade II or higher which occurred within 30 days of surgery. The complications were classified into surgical complications and non-surgical complications. The complications were classified by two researchers according to the Clavien-Dindo classification.

#### Measurement of CrCl

CrCl can be obtained most accurately using 24-hour urine collection, but this method can be too laborious to be practical in routine clinical practice. Therefore, the Cockcroft-Gault (CG) equation (16), the most common equation in routine practice (17), was used to obtain CrCl in this study. Preoperatively, a serum sample containing blood and biochemical indicators was obtained from each patient. After we determined serum creatinine, we converted the units from mg/dL into µmol/L. Using the CG formula, we determined the CrCl.

According to the relevant literature, when the CrCl in adults falls below 80 mL/min, it indicates a decline in glomerular filtration function. If it decreases to 50–70 mL/min, it signifies mild impairment. Therefore, we use a CrCl <70 mL/min as a cutoff point to accurately identify the presence of renal dysfunction (18-20).

#### Statistical methods

The normal distribution of continuous data was determined using the Kolmogorov-Smirnov test. Normally distributed continuous data were shown as mean and standard deviation (SD), whereas non-normally distributed continuous data were shown as median and interquartile range. The categorical data were compared using the Pearson's  $\chi^2$  test or Fisher's exact test. In contrast, non-normally distributed continuous data and ranked data were examined using the Mann-Whitney U test. Meanwhile, the clinically relevant parameters were evaluated using univariate analysis to identify the potential outcome-associated risk factors. The variables with a P value <0.10 on univariate analysis were incorporated in the multivariate (logistic regression) analysis. P values <0.05 were considered statistically significant. SPSS 25.0 (IBM Corp., Armonk, NY, USA) was employed for all statistical analyses.

#### Results

#### **Participants**

We included 543 patients with CRC, 17 of whom were excluded due to the exclusion criteria. The final number of included patients was 526. The two groups were grouped according to CrCl level: and the number of patients in the two groups was 250 (CrCl <70 mL/min) and 276 (CrCl  $\geq$ 70 mL/min), respectively.

#### Outcomes

Demographics of eligible patients are listed in *Table 1*. Overall, 420 of the 526 enrolled patients were above age 60 years. In total, 250 patients had a low CrCl. Meanwhile, 171 patients with a total score of 3 or higher in this study were identified as being at nutritional risk according to the NRS 2002.

As shown in *Table 1*, there was a significant intergroup difference in age, and a low CrCl was more likely to occur in patients above age 60 years (P<0.001). At the same time, patients with a low CrCl had significantly higher NRS score and more comorbidities, along with lower BMI (P<0.001), compared to those with a high CrCl. There is a correlation between NLR and CrCl, and patients with low CrCl have weaker immune function (P=0.012). There was also a significant intergroup difference in terms of complications, and patients with a low CrCl had a higher incidence of complications (P=0.009). There were no significant differences in surgery resection type, operation type, or type of anesthesia between the two groups.

#### Postoperative complications

We divided the postoperative complications into surgery-related complications and non-surgery-related complications (21) (*Table 2*). We found that patients with a low CrCl were more susceptible to surgeryrelated complications. The number and frequency of each complication are shown in *Table 3*. There were 195 postoperative events involving 148 patients (28.14%). Among the patients with complications, 84 (56.76%) had a low CrCl, including 115 postoperative events. Overall, the most frequent postoperative events were infection-related complications, including intra-abdominal infections, wound infection, and pulmonary infection.

### Uni- and multi-variate analyses of variables associated with postoperative complications

Table 4 summarizes the related factors of complications after CRC surgery. Univariate analysis revealed that NRS (P=0.008), CCI (P=0.013), combined resection (P=0.015), anemia (P=0.039), and CrCl (P=0.009) were associated with complications after CRC surgery. NRS, CCI, surgical method, combined resection, anemia, and CrCl were included in the multi-factor analysis because P<0.1. Multivariate logistic regression analysis of these factors identified combined resection [odds ratio (OR) =2.440; P=0.007], CCI (OR =1.321, P=0.014), and CrCl (OR =1.670, P=0.011) as independently influential factors.

#### Uni- and multi-variate analyses of subgroups

We selected the age of 60 years to divide patients into old and young groups. This subgroup analysis revealed significant intergroup differences in the preoperative CrCl. In the old group (Table 5), NRS (P=0.012), CrCl (P=0.009), combined resection (P=0.034), anemia (P=0.033), CCI (P=0.012), and surgery type (P=0.030) were associated with postoperative complications. On multivariate logistic regression analysis, CrCl (OR =1.842, P=0.008), CCI (OR =1.377, P=0.008), and combined resection (OR =2.408, P=0.025) were independently associated factors of postoperative complications of CRC. However, in the young group (Table 6), we found that operating time (OR =2.958, P=0.026) was the only independent influential factor on both uni- and multi-variate analyses. We also found that elderly patients had significantly longer hospital stays than younger patients (P<0.001) as well as higher hospitalization costs (P<0.001).

#### **Discussion**

The current study showed that CrCl is an independent risk factor for short-term postoperative complications in patients with CRC. We also found that CrCl is an independent risk factor for short-term postoperative surgical-related complications in patients with CRC. A CrCl <70 mL/min indicates renal insufficiency (18,19). Therefore, preoperative renal insufficiency is accompanied by an increase in the incidence of short-term surgery-related complications in patients with CRC. Our conclusions are consistent with

| Table 1 | Patient | demograp | hic and | clinical | characteristics |
|---------|---------|----------|---------|----------|-----------------|
|---------|---------|----------|---------|----------|-----------------|

| Factors                              | Total (n=526) <sup>c</sup> | CrCl <70 mL/min (n=250) <sup>c</sup> | CrCl ≥70 mL/min (n=276)° | P value             |
|--------------------------------------|----------------------------|--------------------------------------|--------------------------|---------------------|
| Age                                  |                            |                                      |                          | <0.001 <sup>d</sup> |
| ≤60 y                                | 106                        | 12                                   | 94                       |                     |
| >60 y                                | 420                        | 238                                  | 182                      |                     |
| Gender                               |                            |                                      |                          | 0.117               |
| Male                                 | 313 (59.51)                | 147 (27.95)                          | 166 (31.56)              |                     |
| Female                               | 213 (40.49)                | 103 (19.58)                          | 110 (20.91)              |                     |
| ASA grade                            |                            |                                      |                          | 0.001 <sup>d</sup>  |
| I                                    | 180 (34.22)                | 67 (12.74)                           | 113 (21.48)              |                     |
| II                                   | 279 (53.04)                | 141 (26.81)                          | 138 (26.24)              |                     |
| ≥III                                 | 67 (12.74)                 | 42 (7.98)                            | 25 (4.75)                |                     |
| NRS                                  |                            |                                      |                          | <0.001 <sup>d</sup> |
| <3                                   | 355 (67.49)                | 142 (27.00)                          | 213 (40.49)              |                     |
| ≥3                                   | 171 (32.51)                | 108 (20.53)                          | 63 (11.98)               |                     |
| BMI <sup>b</sup> , kg/m <sup>2</sup> | 22.76 (3.10)               | 21.66 (2.94)                         | 23.76 (2.90)             | <0.001 <sup>d</sup> |
| Operating time, min <sup>a</sup>     | 170.50 [77]                | 170.00 [78]                          | 171.00 [83]              | 0.423               |
| Prior abdominal surgery              |                            |                                      |                          | 0.870               |
| Yes                                  | 112 (21.29)                | 54 (10.27)                           | 58 (11.03)               |                     |
| No                                   | 414 (78.71)                | 196 (37.26)                          | 218 (41.44)              |                     |
| CCI                                  |                            |                                      |                          | 0.001 <sup>d</sup>  |
| 0                                    | 277 (52.66)                | 116 (22.05)                          | 161 (30.61)              |                     |
| 1                                    | 179 (34.03)                | 89 (16.92)                           | 90 (17.11)               |                     |
| ≥2                                   | 70 (13.31)                 | 45 (8.56)                            | 25 (4.75)                |                     |
| Tumor location                       |                            |                                      |                          | 0.295               |
| Rectum                               | 242 (46.01)                | 121 (23.00)                          | 121 (23.00)              |                     |
| Colon                                | 284 (53.99)                | 129 (24.52)                          | 155 (29.47)              |                     |
| Epidural anesthesia                  |                            |                                      |                          | 0.094               |
| Yes                                  | 301 (57.22)                | 153 (29.09)                          | 148 (28.14)              |                     |
| No                                   | 225 (42.78)                | 97 (18.44)                           | 128 (24.33)              |                     |
| Surgical method                      |                            |                                      |                          | 0.109               |
| Laparoscopic surgery                 | 276 (52.47)                | 122 (23.19)                          | 154 (29.28)              |                     |
| Open surgery                         | 250 (47.53)                | 128 (24.33)                          | 122 (23.19)              |                     |
| Combined resection                   |                            |                                      |                          | 0.025 <sup>d</sup>  |
| Yes                                  | 43 (8.17)                  | 13 (2.47)                            | 30 (5.70)                |                     |
| No                                   | 483 (91.83)                | 237 (45.06)                          | 246 (46.77)              |                     |

Table 1 (continued)

| Factors                              | Total (n=526) <sup>c</sup> | CrCl <70 mL/min (n=250)° | CrCl ≥70 mL/min (n=276) <sup>c</sup> | P value            |
|--------------------------------------|----------------------------|--------------------------|--------------------------------------|--------------------|
| TNM stages                           |                            |                          |                                      | 0.929              |
| 1–2                                  | 318 (60.46)                | 152 (28.90)              | 166 (31.56)                          |                    |
| 3–4                                  | 208 (39.54)                | 98 (18.63)               | 110 (20.91)                          |                    |
| Smoking                              |                            |                          |                                      | 0.833              |
| Yes                                  | 99 (18.82)                 | 48 (9.13)                | 51 (9.70)                            |                    |
| No                                   | 427 (81.18)                | 202 (38.40)              | 225 (42.78)                          |                    |
| Drinking                             |                            |                          |                                      | 0.065              |
| Yes                                  | 91 (17.30)                 | 35 (6.65)                | 56 (10.65)                           |                    |
| No                                   | 435 (82.70)                | 215 (40.87)              | 220 (41.83)                          |                    |
| Neutrophil-to-lymphocyte ratio       |                            |                          |                                      | 0.012              |
| ≥3.02                                | 171 (32.51)                | 95 (18.06)               | 76 (14.45)                           |                    |
| <3.02                                | 355 (67.49)                | 155 (29.47)              | 200 (38.02)                          |                    |
| Postoperative complications          |                            |                          |                                      | 0.009 <sup>d</sup> |
| Yes                                  | 148 (28.14)                | 84 (15.97)               | 64 (12.17)                           |                    |
| No                                   | 378 (71.86)                | 166 (31.56)              | 212 (40.30)                          |                    |
| Hemoglobin, g/Lª                     | 120.00 [32]                | 119.00 [28]              | 122.00 [33]                          | 0.133              |
| Serum albumin, g/Lª                  | 37.80 (6.00)               | 36.9 (5.75)              | 38.4 (5.80)                          | 0.461              |
| Serum calcium, mmol/L <sup>b</sup>   | 2.20 (0.14)                | 2.18 (0.14)              | 2.22 (0.14)                          | 0.002 <sup>d</sup> |
| Serum potassium, mmol/L <sup>a</sup> | 3.9 (0.53)                 | 3.91 (0.55)              | 3.88 (0.51)                          | 0.485              |
| Serum sodium, mmol/Lª                | 140 [3]                    | 140 [3]                  | 139 [3]                              | 0.484              |
| Serum chlorine, mmol/Lª              | 105 [4]                    | 105 [4]                  | 105 [3]                              | 0.625              |

<sup>a</sup>, values are median (interquartile range); <sup>b</sup>, values are mean (standard deviation); <sup>c</sup>, values are number of patients and percent unless indicated otherwise; <sup>d</sup>, statistically significant, P<0.05. CrCl, creatinine clearance; y, years; ASA, American Society of Anesthesiology; NRS, nutritional risk screening; BMI, body mass index; CCI, Charlson comorbidity index; TNM, tumor-node-metastasis.

|  | Table 2 Detailed | information on | postoperative | complications |
|--|------------------|----------------|---------------|---------------|
|--|------------------|----------------|---------------|---------------|

| Classification                   | Total (n=526) <sup>a</sup> | CrCl <70 mL/min (n=250) <sup>a</sup> | CrCl ≥70 mL/min (n=276)ª | P value            |
|----------------------------------|----------------------------|--------------------------------------|--------------------------|--------------------|
| Total complications              | 148 (28.14)                | 84 (15.97)                           | 64 (12.17)               | 0.009 <sup>b</sup> |
| Surgery-related complications    | 113 (21.48)                | 65 (12.36)                           | 48 (9.13)                | 0.019 <sup>b</sup> |
| No surgery-related complications | 35 (6.65)                  | 19 (3.61)                            | 16 (3.04)                | 0.484              |

<sup>a</sup>, values are number of patients and percent; <sup>b</sup>, statistically significant. CrCl, creatinine clearance.

those of previous studies that have reported an increased risk of complications due to renal insufficiency in general and vascular (non-cardiac) surgery (22) and an associated increased risk of death and hospitalization as the result of increased disease burden (23). This may be due to the relationship between kidney function and the immune system. Decreasing renal function affects the immune system. In the study, patients with CrCl <70 mL/min had lower immune capacity, which may lead to intestinal barrier dysfunction and increased systemic inflammation (24).

| Infection-related complications           | Total <sup>a</sup> | CrCl <70 mL/min <sup>a</sup> | CrCl ≥70 mL/min <sup>a</sup> |
|---|--------------------|------------------------------|------------------------------|
| Intra-abdominal infection                 | 37 (7.03)          | 24 (4.56)                    | 13 (2.47)                    |
| Wound infection                           | 33 (6.27)          | 16 (3.04)                    | 17 (3.23)                    |
| Pulmonary infection                       | 25 (4.75)          | 14 (2.66)                    | 11 (2.09)                    |
| Venous thrombosis                         | 25 (4.75)          | 17 (3.23)                    | 8 (1.52)                     |
| Anastomotic leakage                       | 20 (3.80)          | 12 (2.28)                    | 8 (1.52)                     |
| Bowel obstruction                         | 15 (2.85)          | 6 (1.14)                     | 9 (1.71)                     |
| Gastrointestinal dysfunction <sup>c</sup> | 8 (1.52)           | 4 (0.76)                     | 4 (0.76)                     |
| Postoperative bleeding                    | 6 (1.14)           | 2 (0.38)                     | 4 (0.76)                     |
| Urinary system                            | 6 (1.14)           | 5 (0.95)                     | 1 (0.19)                     |
| Cardiac complications                     | 2 (0.38)           | 2 (0.38)                     | 0 (0.00)                     |
| Coagulopathy                              | 1 (0.38)           | 0 (0.00)                     | 1 (0.19)                     |
| Pulmonary embolism                        | 2 (0.38)           | 1 (0.19)                     | 1 (0.19)                     |
| Others <sup>b</sup>                       | 15 (2.85)          | 12 (2.28)                    | 3 (0.57)                     |

 Table 3 Actual number and frequency of each complication

Values in parentheses are percentages unless indicated otherwise. <sup>a</sup>, there were some patients who experienced more than one complication category. The total number of the complications was greater than that of the patients who experienced complications; <sup>b</sup>, others contain 4 severe complications (death, autonomic disorder, pulmonary embolism, renal insufficiency) and 2 mild complications (abdominal and pleural effusion); <sup>c</sup>, including postoperative vomiting, diarrhea, gastroparesis, and abdominal distension. CrCl, creatinine clearance.

Concurrently, existing literature shows that a systemic inflammatory response causes a poor prognosis in patients with CRC (25-27).

Patients with renal insufficiency who undergo surgery impose a direct financial burden on society and their families (28-30). This study explored the relationship between preoperative CrCl levels and short-term postoperative complications in CRC surgery. To ensure good renal function, more stringent fluid management and nephrotoxicity avoidance for patients expecting CRC surgery must be implemented. Therefore, hetastarch should be avoided because of its severe adverse effects (31). In contrast, a concentrated albumin solution (20–25%) is a good choice that can provide some benefits (32).

In this study, we found that age had a significant effect on CrCl (33-35), so we grouped patients by age and performed a subgroup analysis. Between the two groups, there was a significant difference in the effect of low CrCl on postoperative complications. In the elderly group, patients with a low CrCl were more likely to have postoperative complications, whereas there was no significant effect in the young group. This phenomenon may have a certain relationship with age itself since the decrease in CrCl with age represents true renal aging (34,36) and renal function decreases with age (37,38). Another possible reason is that elderly patients often have impaired nutritional status, especially those admitted to the hospital (39). However, young patients have better physical compensatory abilities because their compensated kidney function is still normal, thus reducing the preoperative prognosis value.

In China, the direct treatment of CRC may sometimes be catastrophic for CRC patients (40). In our study, we found that older patients had significantly longer hospital stays and more expensive hospitalization costs than younger adults. Thus, a poor prognosis can increase the economic burden on society and families. Therefore, more attention should be paid to the adjustment of the preoperative condition of elderly patients and to the maintenance of stable kidney function preoperatively (41-43). For young people, this requirement may not be very strict, but it is still necessary to maintain good renal function.

In this study, some of our patients underwent multiorgan combined resection, including the liver, gallbladder, and spleen. Related studies have shown that the incidence

|                         | Total            | Univariate analysis                    |   |                    | Multivariate analysis |                    |  |
|-------------------------|------------------|--|---|--------------------|-----------------------|--------------------|--|
| Factors                 | Total<br>(n=526) | Postoperative<br>complications (n=148) | Non-postoperative complications (n=378) | P value            | OR (95% CI)           | P value            |  |
| Age                     |                  |  |   | 0.718              |                       |                    |  |
| >60 y                   | 420              | 120                                    | 300                                     |                    |                       |                    |  |
| ≤60 y                   | 106              | 28                                     | 78                                      |                    |                       |                    |  |
| Gender                  |                  |  |   | 0.989              |                       |                    |  |
| Male                    | 313              | 88                                     | 225                                     |                    |                       |                    |  |
| Female                  | 213              | 60                                     | 153                                     |                    |                       |                    |  |
| ASA grade               |                  |  |   | 0.108              |                       |                    |  |
| 1                       | 180              | 46                                     | 134                                     |                    |                       |                    |  |
| II                      | 279              | 77                                     | 202                                     |                    |                       |                    |  |
| ≥III                    | 67               | 25                                     | 42                                      |                    |                       |                    |  |
| NRS                     |                  |  |   | 0.008 <sup>a</sup> |                       |                    |  |
| <3                      | 355              | 87                                     | 268                                     |                    |                       |                    |  |
| ≥3                      | 171              | 61                                     | 110                                     |                    |                       |                    |  |
| BMI, kg/m <sup>2</sup>  |                  |  |   | 0.818              |                       |                    |  |
| <18.5                   | 45               | 14                                     | 31                                      |                    |                       |                    |  |
| 18.5–24                 | 303              | 84                                     | 219                                     |                    |                       |                    |  |
| >24                     | 178              | 50                                     | 129                                     |                    |                       |                    |  |
| Operating time          |                  |  |   | 0.425              |                       |                    |  |
| >210 min                | 133              | 41                                     | 92                                      |                    |                       |                    |  |
| ≤210 min                | 393              | 107                                    | 286                                     |                    |                       |                    |  |
| Prior abdominal surgery | /                |  |   | 0.725              |                       |                    |  |
| Yes                     | 112              | 33                                     | 79                                      |                    |                       |                    |  |
| No                      | 414              | 115                                    | 299                                     |                    |                       |                    |  |
| CCI                     |                  |  |   | 0.013 <sup>a</sup> | 1.321 (1.058–1.650)   | 0.014 <sup>a</sup> |  |
| 0                       | 277              | 68                                     | 209                                     |                    |                       |                    |  |
| 1                       | 179              | 52                                     | 127                                     |                    |                       |                    |  |
| ≥2                      | 70               | 28                                     | 42                                      |                    |                       |                    |  |
| Tumor location          |                  |  |   | 0.571              |                       |                    |  |
| Rectum                  | 242              | 71                                     | 171                                     |                    |                       |                    |  |
| Colon                   | 284              | 77                                     | 207                                     |                    |                       |                    |  |
| Epidural anesthesia     |                  |  |   | 0.892              |                       |                    |  |
| Yes                     | 301              | 84                                     | 217                                     |                    |                       |                    |  |
| No                      | 225              | 64                                     | 161                                     |                    |                       |                    |  |
| Surgical method         |                  |  |   | 0.065              |                       |                    |  |
| Laparoscopic surgery    | 276              | 68                                     | 208                                     |                    |                       |                    |  |
| Open surgery            | 250              | 80                                     | 170                                     |                    |                       |                    |  |

Table 4 Univariate and multivariate logistic regression analysis of factors associated with postoperative complications

Table 4 (continued)

Table 4 (continued)

|                    | Total   | Ur                                  | Multivariate analysis                      |                    |                     |                    |  |
|--------------------|---------|-------------------------------------|--|--------------------|---------------------|--------------------|--|
| Factors            | (n=526) | Postoperative complications (n=148) | Non-postoperative<br>complications (n=378) | P value            | OR (95% Cl)         | P value            |  |
| Combined resection |         |                                     |  | 0.015ª             | 2.440 (1.269–4.692) | 0.007 <sup>a</sup> |  |
| Yes                | 43      | 19                                  | 24   |                    |                     |                    |  |
| No                 | 483     | 129                                 | 354  |                    |                     |                    |  |
| TNM stages         |         |                                     |  | 0.428              |                     |                    |  |
| 1–2                | 318     | 94                                  | 224  |                    |                     |                    |  |
| 3–4                | 208     | 54                                  | 154  |                    |                     |                    |  |
| Smoking            |         |                                     |  | 0.202              |                     |                    |  |
| Yes                | 99      | 33                                  | 66   |                    |                     |                    |  |
| No                 | 427     | 115                                 | 312  |                    |                     |                    |  |
| Drinking           |         |                                     |  | 0.721              |                     |                    |  |
| Yes                | 91      | 27                                  | 64   |                    |                     |                    |  |
| No                 | 435     | 121                                 | 314  |                    |                     |                    |  |
| Hypoalbuminemia    |         |                                     |  | 0.180              |                     |                    |  |
| Yes                | 31      | 12                                  | 19   |                    |                     |                    |  |
| No                 | 495     | 136                                 | 359  |                    |                     |                    |  |
| Anemia             |         |                                     |  | 0.039 <sup>a</sup> |                     |                    |  |
| Yes                | 167     | 57                                  | 110  |                    |                     |                    |  |
| No                 | 359     | 91                                  | 268  |                    |                     |                    |  |
| Hypocalcemia       |         |                                     |  | 0.385              |                     |                    |  |
| Yes                | 261     | 78                                  | 183  |                    |                     |                    |  |
| No                 | 265     | 70                                  | 195  |                    |                     |                    |  |
| Hypokalemia        |         |                                     |  | >0.99              |                     |                    |  |
| Yes                | 68      | 19                                  | 49   |                    |                     |                    |  |
| No                 | 458     | 129                                 | 329  |                    |                     |                    |  |
| Hyponatremia       |         |                                     |  | >0.99              |                     |                    |  |
| Yes                | 19      | 5                                   | 14   |                    |                     |                    |  |
| No                 | 507     | 143                                 | 364  |                    |                     |                    |  |
| Hypochloremia      |         |                                     |  | >0.99              |                     |                    |  |
| Yes                | 4       | 1                                   | 3  |                    |                     |                    |  |
| No                 | 522     | 147                                 | 375  |                    |                     |                    |  |
| CrCl               |         |                                     |  | 0.009 <sup>a</sup> | 1.670 (1.123–2.482) | 0.011 <sup>ª</sup> |  |
| <70 mL/min         | 250     | 84                                  | 166  |                    |                     |                    |  |
| ≥70 mL/min         | 276     | 64                                  | 212  |                    |                     |                    |  |

<sup>a</sup>, statistically significant (P<0.05). OR, odds ratio; CI, confidence interval; y, years; ASA, American Society of Anesthesiology; NRS, nutritional risk screening, BMI, body mass index; CCI, Charlson comorbidity index; TNM, tumor-node-metastasis; CrCI, creatinine clearance.

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|                         | Univariate analysis   |    |         | Multivariate analysis |                     |                    |
|-------------------------|---|----|---------|-----------------------|---------------------|--------------------|
| Factors                 | ors Total<br>(n=420) Postoperative Non-postoperative<br>complications (n=120) complications (n=300) P value |    | P value | OR (95% CI)           | P value             |                    |
| Gender                  |   |    |         | 0.590                 |                     |                    |
| Male                    | 257   | 71 | 186     |                       |                     |                    |
| Female                  | 163   | 49 | 114     |                       |                     |                    |
| ASA grade               |   |    |         | 0.063                 |                     |                    |
| I                       | 113   | 27 | 86      |                       |                     |                    |
| II                      | 243   | 69 | 174     |                       |                     |                    |
| ≥III                    | 64  | 24 | 40      |                       |                     |                    |
| NRS                     |   |    |         | 0.012ª                |                     |                    |
| <3                      | 260   | 63 | 197     |                       |                     |                    |
| ≥3                      | 160   | 57 | 103     |                       |                     |                    |
| BMI, kg/m <sup>2</sup>  |   |    |         | 0.939                 |                     |                    |
| <18.5                   | 38  | 12 | 26      |                       |                     |                    |
| 18.5–24                 | 244   | 67 | 177     |                       |                     |                    |
| >24                     | 138   | 41 | 97      |                       |                     |                    |
| Operating time          |   |    |         | 0.902                 |                     |                    |
| >210 min                | 108   | 30 | 78      |                       |                     |                    |
| ≤210 min                | 312   | 90 | 222     |                       |                     |                    |
| Prior abdominal surgery |   |    |         | 0.795                 |                     |                    |
| Yes                     | 92  | 25 | 67      |                       |                     |                    |
| No                      | 328   | 95 | 233     |                       |                     |                    |
| CCI                     |   |    |         | 0.012ª                | 1.377 (1.087–1.744) | 0.008 <sup>a</sup> |
| 0                       | 195   | 46 | 149     |                       |                     |                    |
| 1                       | 156   | 47 | 109     |                       |                     |                    |
| ≥2                      | 69  | 27 | 42      |                       |                     |                    |
| Tumor location          |   |    |         | 0.478                 |                     |                    |
| Rectum                  | 202   | 61 | 141     |                       |                     |                    |
| Colon                   | 218   | 59 | 159     |                       |                     |                    |
| Epidural anesthesia     |   |    |         | 0.635                 |                     |                    |
| Yes                     | 256   | 71 | 185     |                       |                     |                    |
| No                      | 164   | 49 | 115     |                       |                     |                    |
| Surgical method         |   |    |         | 0.030 <sup>a</sup>    |                     |                    |
| Laparoscopic surgery    | 201   | 47 | 154     |                       |                     |                    |
| Open surgery            | 219   | 73 | 146     |                       |                     |                    |

| Table 5 Univariate and | d multivariate logisti | regression analy | vsis of factors a | ssociated with post | operative com | plications of elderly patient | ts |
|------------------------|------------------------|------------------|-------------------|---------------------|---------------|-------------------------------|----|
|                        |                        |                  |                   |                     |               |                               |    |

Table 5 (continued)

Table 5 (continued)

|                    | Total   | U                                      | nivariate analysis                         | Multivariate analysis |                     |                    |
|--------------------|---------|--|--|-----------------------|---------------------|--------------------|
| Factors            | (n=420) | Postoperative<br>complications (n=120) | Non-postoperative<br>complications (n=300) | P value               | OR (95% CI)         | P value            |
| Combined resection |         |  |  | 0.034ª                | 2.408 (1.118–5.189) | 0.025ª             |
| Yes                | 31      | 14                                     | 17   |                       |                     |                    |
| No                 | 389     | 106                                    | 283  |                       |                     |                    |
| TNM stages         |         |  |  | 0.440                 |                     |                    |
| 1–2                | 257     | 77                                     | 180  |                       |                     |                    |
| 3–4                | 163     | 43                                     | 120  |                       |                     |                    |
| Smoking            |         |  |  | 0.502                 |                     |                    |
| Yes                | 79      | 25                                     | 54   |                       |                     |                    |
| No                 | 341     | 95                                     | 246  |                       |                     |                    |
| Drinking           |         |  |  | 0.885                 |                     |                    |
| Yes                | 69      | 19                                     | 50   |                       |                     |                    |
| No                 | 351     | 101                                    | 250  |                       |                     |                    |
| Hypoalbuminemia    |         |  |  | 0.078                 |                     |                    |
| Yes                | 25      | 11                                     | 14   |                       |                     |                    |
| No                 | 395     | 109                                    | 286  |                       |                     |                    |
| Anemia             |         |  |  | 0.033ª                |                     |                    |
| Yes                | 139     | 49                                     | 90   |                       |                     |                    |
| No                 | 281     | 71                                     | 210  |                       |                     |                    |
| Hypocalcemia       |         |  |  | 0.130                 |                     |                    |
| Yes                | 219     | 70                                     | 149  |                       |                     |                    |
| No                 | 201     | 50                                     | 151  |                       |                     |                    |
| Hypokalemia        |         |  |  | >0.99                 |                     |                    |
| Yes                | 54      | 15                                     | 39   |                       |                     |                    |
| No                 | 366     | 105                                    | 261  |                       |                     |                    |
| Hyponatremia       |         |  |  | >0.99                 |                     |                    |
| Yes                | 15      | 4                                      | 11   |                       |                     |                    |
| No                 | 405     | 116                                    | 289  |                       |                     |                    |
| Hypochloremia      |         |  |  | 0.501                 |                     |                    |
| Yes                | 2       | 1                                      | 1  |                       |                     |                    |
| No                 | 418     | 119                                    | 299  |                       |                     |                    |
| CrCl               |         |  |  | 0.009 <sup>a</sup>    | 1.842 (1.171–2.897) | 0.008 <sup>a</sup> |
| <70 mL/min         | 238     | 80                                     | 158  |                       |                     |                    |
| ≥70 mL/min         | 182     | 40                                     | 142  |                       |                     |                    |

<sup>a</sup>, statistically significant (P<0.05). OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiology; NRS, nutritional risk screening, BMI, body mass index; CCI, Charlson comorbidity index; TNM, tumor-node-metastasis; CrCI, creatinine clearance.

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| Factors                 | Total<br>(n=106) | Univariate analysis                   |  |         | Multivariate analysis |         |
|-------------------------|------------------|---------------------------------------|--|---------|-----------------------|---------|
|                         |                  | Postoperative<br>complications (n=28) | Non-postoperative complications (n=78) | P value | OR (95% CI)           | P value |
| Gender                  |                  |                                       |  | 0.382   |                       |         |
| Male                    | 50               | 17                                    | 39                                     |         |                       |         |
| Female                  | 56               | 11                                    | 39                                     |         |                       |         |
| ASA grade               |                  |                                       |  | 0.659   |                       |         |
| I                       | 67               | 19                                    | 48                                     |         |                       |         |
| II                      | 36               | 8                                     | 28                                     |         |                       |         |
| ≥III                    | 3                | 1                                     | 2                                      |         |                       |         |
| NRS                     |                  |                                       |  | 0.429   |                       |         |
| <3                      | 95               | 24                                    | 71                                     |         |                       |         |
| ≥3                      | 11               | 4                                     | 7                                      |         |                       |         |
| BMI, kg/m <sup>2</sup>  |                  |                                       |  | 0.522   |                       |         |
| <18.5                   | 7                | 2                                     | 5                                      |         |                       |         |
| 18.5–24                 | 59               | 17                                    | 42                                     |         |                       |         |
| >24                     | 40               | 9                                     | 31                                     |         |                       |         |
| Operating time          |                  |                                       |  | 0.023ª  | 2.958 (1.140–7.677)   | 0.026ª  |
| >210 min                | 25               | 11                                    | 14                                     |         |                       |         |
| ≤210 min                | 81               | 17                                    | 64                                     |         |                       |         |
| Prior abdominal surgery |                  |                                       |  | 0.126   |                       |         |
| Yes                     | 20               | 8                                     | 12                                     |         |                       |         |
| No                      | 86               | 20                                    | 66                                     |         |                       |         |
| CCI                     |                  |                                       |  | 0.846   |                       |         |
| 0                       | 82               | 22                                    | 60                                     |         |                       |         |
| 1                       | 23               | 5                                     | 18                                     |         |                       |         |
| ≥2                      | 1                | 1                                     | 0                                      |         |                       |         |
| Tumor location          |                  |                                       |  | 0.825   |                       |         |
| Rectum                  | 40               | 10                                    | 30                                     |         |                       |         |
| Colon                   | 66               | 18                                    | 48                                     |         |                       |         |
| Epidural anesthesia     |                  |                                       |  | 0.620   |                       |         |
| Yes                     | 45               | 13                                    | 32                                     |         |                       |         |
| No                      | 61               | 15                                    | 46                                     |         |                       |         |
| Surgical method         |                  |                                       |  | 0.635   |                       |         |
| Laparoscopic surgery    | 75               | 21                                    | 54                                     |         |                       |         |
| Open surgery            | 31               | 7                                     | 24                                     |         |                       |         |

Table 6 Univariate and multivariate logistic regression analysis of factors associated with postoperative complications of young patients

Table 6 (continued)

Table 6 (continued)

| Factors            | Total<br>(n=106) | Univariate analysis                   |   |         | Multivariate analysis |         |
|--------------------|------------------|---------------------------------------|---|---------|-----------------------|---------|
|                    |                  | Postoperative<br>complications (n=28) | Non-postoperative<br>complications (n=78) | P value | OR (95% CI)           | P value |
| Combined resection |                  |                                       |   | 0.203   |                       |         |
| Yes                | 12               | 5                                     | 7   |         |                       |         |
| No                 | 94               | 23                                    | 71  |         |                       |         |
| TNM stages         |                  |                                       |   | 0.824   |                       |         |
| 1–2                | 61               | 17                                    | 44  |         |                       |         |
| 3–4                | 45               | 11                                    | 34  |         |                       |         |
| Smoking            |                  |                                       |   | 0.126   |                       |         |
| Yes                | 20               | 8                                     | 12  |         |                       |         |
| No                 | 86               | 20                                    | 66  |         |                       |         |
| Drinking           |                  |                                       |   | 0.234   |                       |         |
| Yes                | 22               | 8                                     | 14  |         |                       |         |
| No                 | 84               | 20                                    | 64  |         |                       |         |
| Hypoalbuminemia    |                  |                                       |   | >0.99   |                       |         |
| Yes                | 6                | 1                                     | 5   |         |                       |         |
| No                 | 100              | 27                                    | 73  |         |                       |         |
| Anemia             |                  |                                       |   | 0.790   |                       |         |
| Yes                | 28               | 8                                     | 20  |         |                       |         |
| No                 | 77               | 20                                    | 57  |         |                       |         |
| Hypocalcemia       |                  |                                       |   | 0.184   |                       |         |
| Yes                | 42               | 8                                     | 34  |         |                       |         |
| No                 | 64               | 20                                    | 44  |         |                       |         |
| Hypokalemia        |                  |                                       |   | 0.844   |                       |         |
| Yes                | 14               | 4                                     | 10  |         |                       |         |
| No                 | 92               | 24                                    | 68  |         |                       |         |
| Hyponatremia       |                  |                                       |   | >0.99   |                       |         |
| Yes                | 4                | 1                                     | 3   |         |                       |         |
| No                 | 102              | 27                                    | 75  |         |                       |         |
| Hypochloremia      |                  |                                       |   | >0.99   |                       |         |
| Yes                | 2                | 0                                     | 2   |         |                       |         |
| No                 | 104              | 28                                    | 76  |         |                       |         |
| CrCl               |                  |                                       |   | 0.564   |                       |         |
| <70 mL/min         | 12               | 4                                     | 8   |         |                       |         |
| ≥70 mL/min         | 94               | 24                                    | 70  |         |                       |         |

<sup>a</sup>, statistically significant (P<0.05). OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiology; NRS, nutritional risk screening; BMI, body mass index; CCI, Charlson comorbidity index; TNM, tumor-node-metastasis; CrCI, creatinine clearance.

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of postoperative complications is higher in cases of multiple organ resection (44-46). This finding is consistent with our study, in which multi-organ combined resection was a significant independent risk factor for short-term complications after CRC. The reason for this may be related to greater tissue damage and larger incisions resulting from multi-organ combined resection surgery. However, combined resection can reduce the burden on the heart and lungs associated with multiple anesthesia exposures and can reduce hospitalization costs (47). Therefore, for patients who require multiple organ resection, we recommend the surgery be performed by an experienced team and adequate intensive care be provided to reduce postoperative risk, especially for elderly patients.

Elderly patients with CRC often have multiple comorbidities. We can use the most extensive CCI system, and CCI can be applied to most malignant tumors (48). In this study, CCI was an important predictor of short-term postoperative complications in patients with CRC. Elderly patients with greater CCI may have a higher incidence of postoperative complications. Therefore, for these patients, we need to consider surgery for CRC after treating the comorbidities.

This present study had several limitations. First, we used the CG formula for creatinine measurements instead of urine CrCl. This may have led to a degree of deviation between the CrCl used in the CG formula and the actual CrCl of the same patient. Second, large-scale, multi-center studies are needed to analyze whether this relationship exists in other regions since this was a single-center study with a relatively small sample size. Third, for the age category analysis, we used a cutoff at 60 years, and an analysis of other age categories is required in the future. Fourth, like all retrospective studies, ours could have possible errors in data collection and was susceptible to selection bias.

#### Conclusions

This study explored the relationship between preoperative CrCl levels and short-term postoperative complications in CRC surgery. A low CrCl, multi-organ combined resection, and CCI were independent risk factors for short-term complications. For the elderly, the incidence of postoperative complications was significantly increased with low CrCl and multi-organ resection. Therefore, we must optimize the patient's renal function preoperatively and provide more intensive postoperative monitoring for elderly CRC surgery patients.

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#### Footnote

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*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Ethics Committee of The First Affiliated Hospital of Wenzhou Medical University (2015-No.023) and individual consent for this retrospective analysis was waived.

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