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Effects of sarcopenia, hypoalbuminemia, and laparoscopic surgery on postoperative complications in elderly patients with colorectal cancer: A prospective study

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With the increasing number of elderly patients, the risk of diseases such as colorectal cancer (CRC) has increased. The objective of this prospective study was to explore the effects of sarcopenia, hypoalbuminemia, and laparoscopic surgery on postoperative complications among elderly patients who recently underwent colorectal surgery. Patients aged over 65 years who underwent surgery for CRC at the First Affiliated Hospital of Wenzhou Medical University were considered for this study. The demographical and clinical characteristics of these patients, as well as postoperative complications, were prospectively analyzed. The patients were divided into two groups depending on the diagnosis of sarcopenia, and the clinical variables corresponding to the two groups were compared. Further, the risk factors associated with postoperative complications were evaluated using univariate analysis and multivariate logistic regression analysis. A total of 360 patients fulfilled the inclusion criteria. Incidences of postoperative complications in the sarcopenia and non-sarcopenia groups were at 38.3% and 27.3%, respectively. In addition, sarcopenia (p=0.029) and hypoalbuminemia (p=0.010) were identified as independent risk factors, while laparoscopic surgery (p=0.023) was identified as a protective factor for postoperative complications. However, laparoscopic surgery was a protective factor for postoperative complications in the colon group only (p=0.001). Sarcopenia and hypoalbuminemia are independent risk factors that influence the probability of developing complications following CRC surgery. Laparoscopic surgery is a protective factor for postoperative complications of CRC patients, particularly colon cancer patients.

Key words: colorectal cancer, postoperative complications, old age, sarcopenia, hypoalbuminemia, laparoscopic surgery

Colorectal cancer (CRC) is one of the most frequently encountered malignancies, being the third and second most common disease in terms of incidence (10.2%) and mortality (9.2%), respectively [1, 2]. Eventually, the number of elderly patients receiving surgical treatment for CRC will increase in China, as surgical resection is the primary treatment for CRC [3].

The postoperative complication rate for CRC ranges from 18–38% [4–8]. However, most of the elderly individuals are also associated with other comorbidities, such as pulmonary or cardiovascular diseases, which increase the risk of postoperative complications. Therefore, it is necessary to analyze the risk factors pertaining to postoperative complications among elderly CRC patients.

Typically, favorable prognoses for elderly cancer patients depend on their physical conditions [9], which can be broadly expressed based on their nutrition status. According to a related study, malnutrition is a risk factor affecting the incidence of postoperative complications [10], and sarcopenia is a major indicator of malnutrition [11]. Sarcopenia is defined as the progressive and extensive loss of skeletal muscle mass and muscle function (strength or physical performance) [12, 13], and this may increase the incidence of postoperative complications. Moreover, the incidence of sarcopenia increases with age. As reported in some related studies, lower muscle density may also increase the risk of postoperative death and the incidence of complications; thus, it negatively affects the elderly population [14, 15].

Hypoalbuminemia is also a manifestation of poor nutritional status. Its relationship with adverse surgical outcomes has been recognized [16]. When the human body lacks serum albumin, it causes a variety of adverse reactions because serum albumin participates in various physiological mechanisms of the human body. Therefore, in elderly patients with CRC, we consider that hypoalbuminemia may also affect the occurrence of postoperative complications.

From the time when laparoscopy was established as a surgical technique, it is being widely used for many types of surgeries. Compared to conventional surgery, laparoscopic surgery is a minimally invasive procedure that can reduce the probability of developing postoperative complications [17]. Actually, however, elderly patients often exhibit declining cardiopulmonary function and other complications. Moreover, there is a major controversy on whether laparoscopic surgery is suitable for elderly CRC patients. Therefore, this prospective study was conducted to explore the effects of sarcopenia, hypoalbuminemia, and laparoscopic surgery on postoperative complications in elderly CRC patients.

Patients and methods

Patients. The Gastrointestinal Surgical Department at the First Affiliated Hospital of Wenzhou Medical University (Wenzhou) recruited 364 CRC patients from January 2016 to December 2018. All the patients fulfilled the following criteria: 1/ ≥65 years of age [18]; 2/ definitive diagnosis of CRC; 3/ planning to undergo elective colorectal surgery for CRC; 4/ abdomen computed tomography (CT) performed within two weeks before the surgery in this hospital. Four patients were later excluded because of the following criteria: 1/ received preoperative chemotherapy or radiotherapy; 2/ palliative surgery; or 3/ emergency surgery. Thus, in total, 360 patients were selected for our analysis. Laparoscopic surgery was recommended to all patients. However, some people opted for open surgery because they had previous abdominal surgery or did not consent to laparoscopic surgery for financial reasons. All the operations were performed by experienced surgeons, each of whom had worked on over 50 CRC cases. Each patient signed an informed consent form to participate in this study. The study protocol was approved by the Ethics Committee of the First Affiliated Hospital of Wenzhou Medical University (2014 NO.063).

Data extraction. The following parameters were collected from all patients: a/ patient characteristics, including age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) grade, preoperative hemoglobin concentration (hemoglobin concentration of <120 g/l for males and <110 g/l for females is defined as anemia), preoperative plasma albumin concentration (plasma albumin concentration of <35 g/l is defined as hypoalbuminemia), comorbidity (calculated using the Charlson comorbidity index score), preoperative nutritional risk score (evaluated according to Nutritional Risk Screening (NRS) 2002 [19] within 24 h after admission where a score of three or more identifies a patient with nutritional risk), total abdominal muscle area (TAMA), L3 skeletal muscle index (L3 SMI), previous abdominal surgery history and tumor-node-metastasis stage of the tumor; b/ operation details, including the resection type (rectum or colon), operation type (laparoscopic surgery or laparotomy), type of anesthesia (epidural anesthesia or general anesthesia), combined resection, and operation time; and c/ postoperative outcomes, including postoperative complications within 30 days after surgery, length of stay, and hospitalization costs.

Postoperative complications were defined as symptoms consistent with the Clavien-Dindo classification [20] criteria and those occurring within 30 days of surgery. The complications were classified by two researchers based on the Clavien–Dindo classification. The number of postoperative complications was defined as Grade II or higher.

Definition of sarcopenia. According to the Asian Working Group for Sarcopenia [13], sarcopenia is defined as low skeletal muscle mass combined with low muscle function (defined by strength or physical performance). The muscle mass can be measured using third lumbar cross-sectional CT images [21]. A trained researcher supervised by a senior radiologist manually delineated the organization and analyzed the CT images to measure the TAMA with a dedicated processing system (version 3.0.11.3 BN17 32; INFINITT Healthcare Co., Ltd.), blinded for the patient and surgical features. We used a predetermined Hounsfield unit (HU) threshold for specific tissue boundaries, with HU values from –29 to +150 representing skeletal muscle. The TAMA was normalized to height squared (m^2) and reported as the L3 skeletal muscle index (cm^2/m^2).

The muscle strength and physical performance were assessed using the preoperative grip strength and 6 m usual gait speed, respectively [13]. All the patients used their dominant hands to squeeze an electronic hand dynamometer (EH101; Zhongshan Camry Electronic Co. Ltd., Guangdong Province, China). Moreover, they were asked to cross a distance of 6 m at their usual gait speed, and the duration from the first step to the last step over was recorded. Both the tests were conducted within 7 d prior to surgery, and the maximal values obtained from three consecutive tests were recorded [22].

According to racial specificity, the patients were considered sarcopenic when they showed the following conditions: 1/ low muscle mass (L3 skeletal muscle index of ≤40.8 cm/m for males and ≤34.9 cm/m for females) [23]; 2/ low muscle strength (hand grip strength of <26 kg for males and <18 kg for females); and 3/ low muscle performance (6 m travel speed of <0.8 m/s) [13].

Statistical analysis. The Kolmogorov–Smirnov test was conducted to determine the normal distribution of continuous data. Typically, normally distributed continuous data are expressed using their mean and standard deviation values, while continuous data not conforming to a normal distribution are expressed using the median and interquartile range.

The categorical data were compared using the Pearson's χ^2 test or Fisher's exact test. In contrast, non-normally distributed continuous data and ranked data used the Mann–Whitney U test. Further, clinically relevant parameters were evaluated using the univariate analysis to identify the potential outcome-associated risk factors. Variables with a p-value <0.10 in univariate analysis were incorporated into multivariate (logistic regression) analysis. A difference of $p<0.05$ was considered statistically significant. The SPSS software for Windows (version 25.0 IBM; SPSS Inc., Armonk, New York, USA) was employed for all the statistical analyses.

Results

Patient population and grouping. Table 1 presents the characteristics of the 360 CRC patients included in the study. Overall, there were 214 (59.4%) male patients. The patients were divided into two groups according to the presence (n=133) or absence of sarcopenia (n=227). The rates of postoperative complications corresponding to the sarcopenia group and non-sarcopenia group were 38.35% and 27.31%, respectively, and the mean BMI values of the two groups were 21.63 and 23.21, respectively. Overall, patients with sarcopenia were older (p=0.004) and had a lower BMI (p<0.001), more postoperative complications (p=0.029), longer hospital stays (p<0.001), and incurred higher hospitalization costs (p<0.001), compared to the non-sarcopenia patients. There were no significant differences in terms of the NRS, the Charlson comorbidity index, surgery resection type, operation type, or type of anesthesia between the two groups.

Number and frequency of each complication. There were 153 postoperative events involving 113 patients (31.39%). Among them, there were 51 patients with sarcopenia, including 71 postoperative events. In addition, the incidence of complications in the sarcopenia group was 38.35%. The actual number and frequency of each complication are given in Table 2. Among these complications, infection-related complications were the most frequent, including wound infection, intra-abdominal infection, and pulmonary infection. The second most common event was persistent hypoalbuminemia that required long-term use of concentrated albumin blood product solution (20–25%) for nutritional support.

Table 1. Demographic and clinical characteristics of patients.

Factor	Total (n=360) [a]	Sarcopenia (n=133) [a]	No sarcopenia (n=227) [a]	p-value
Age, Years[++]	72 (11.0)	76 (11.0)	71 (10.0)	0.004 *
BMI[+]	22.63 (3.23)	21.63 (2.77)	23.21 (3.35)	<0.001 *
Albumin, g/L [++]	36.6 (5.48)	36.4 (5.35)	36.8 (5.90)	0.349
Hemoglobin, g/L[++]	116.0 (32)	114.0 (33)	119.0 (32)	0.315
Gender				0.496
Male	214 (59.4%)	76 (21.1%)	138 (38.3%)	
Female	146 (40.6%)	57 (15.8%)	89 (24.7%)	
ASA grade				0.003 *
I	51 (14.2%)	30 (8.3%)	21 (5.8%)	
II	248 (68.9%)	82 (22.8%)	166 (46.1%)	
III	61 (16.9%)	21 (5.8%)	40 (11.1%)	
NRS				0.743
<3	193 (53.6%)	73 (20.3%)	120 (33.3%)	
≥3	167 (46.4%)	60 (16.7%)	107 (29.7%)	
Operating time, min [++]				0.310
>210min	240 (65)	240 (38)	240 (65)	
≤210min	150 (58)	150 (60)	150 (50)	
Prior abdominal Surgery				0.158
Yes	66 (18.3%)	19 (5.3%)	47 (13.1%)	
No	294 (81.7%)	114 (31.7)	180 (50.0%)	
Charlson comorbidity index				0.283
0	133 (36.9%)	56 (15.6%)	77 (21.4%)	
1	151 (42.0%)	50 (13.9%)	101 (28.1%)	
≥2	76 (21.1%)	27 (7.5%)	49 (13.6%)	
Tumor location				0.739
Rectum	146 (40.6%)	52 (14.4%)	94 (26.1%)	
Colon	214 (59.4%)	81 (22.5%)	133 (36.9%)	

Table 1. Continued ...

Factor	Total (n=360) [a]	Sarcopenia (n=133) [a]	No sarcopenia (n=227) [a]	p-value
Epidural anesthesia				1.000
Yes	253 (70.3%)	94 (26.1%)	159 (44.2%)	
No	107 (29.7%)	39 (10.8%)	68 (18.9%)	
General anesthesia				0.730
Yes	348 (96.7%)	128 (35.6%)	220 (61.1%)	
No	12 (3.3%)	5 (1.4%)	7 (1.9%)	
Operation type				0.490
Laparoscopic surgery	123 (34.2%)	42 (11.7%)	81 (22.5%)	
Open surgery	237 (65.8%)	91 (25.3%)	146 (40.6%)	
Combined resection				0.771
Yes	20 (5.6%)	8 (2.2%)	12 (3.3%)	
No	340 (94.4%)	125 (34.7%)	215 (59.7%)	
TNM stage				0.429
1–2	218 (60.6%)	77 (21.4%)	141 (39.2%)	
3–4	142 (39.4%)	56 (15.6%)	86 (23.9%)	
Postoperative complications				0.029 *
Yes	113 (31.4%)	51 (14.2%)	62 (17.2%)	
No	247 (68.6%)	82 (22.8%)	165 (45.8%)	
Duration of hospital stay, DAYS [++]	19 (9)	20.00 (10)	19 (9)	0.444
Costs, RMB [++]	50956.92 (21010.22)	48558.28 (22439.86)	52905.64 (20385.51)	1.000
Readmissions within 30 days of discharge	12 (3.33%)	10 (2.78%)	2 (0.55%)	0.371

ASA = American Society of Anesthesiology; BMI = body mass index; TNM = tumor-node-metastasis; NRS = nutritional risk screening
[++]represents medians (inter quartile range); [+]indicates means (standard deviation); [a]indicates the number of patients and percentage unless indicated otherwise; *statistically significant p<0.05

Table 2. Actual number and frequency of each complication.

Complication[a]a	Total (n=113)[c]	Sarcopenia group (n=51)[c]	No sarcopenia group (n = 62)[c]
Infection-related complications			
Wound infection	32 (8.89%)	14 (3.89%)	18 (5.00%)
Intra-abdominal infection	21 (5.83%)	8 (2.22%)	13 (3.61%)
Respiratory tract infection	18 (5.00%)	8 (2.22%)	10 (2.78%)
Persistent hypoalbuminemia	17 (4.72%)	10 (2.78%)	7 (1.94%)
Anastomotic leakage	13 (3.61%)	4 (1.11%)	9 (2.50%)
Venous thrombosis	11 (3.05%)	4 (1.11%)	7 (1.94%)
Bowel obstruction	9 (2.50%)	3 (0.83%)	6 (1.67%)
Diarrhea	4 (1.11%)	2 (0.55%)	2 (0.55%)
Pleural effusion	4 (1.11%)	2 (0.55%)	2 (0.55%)
Urinary system	6 (1.67%)	4 (1.11%)	2 (0.55%)
Postoperative bleeding	7 (1.94%)	5 (1.39%)	2 (0.55%)
Cardiac complications	2 (0.55%)	2 (0.55%)	0 (0.00%)
Hepatic complications	1 (0.28%)	0 (0.00%)	1 (0.28%)
Others[b]	8 (2.22%)	5 (1.39%)	3 (0.83%)

[a]some patients have more than one type of postoperative complication. The total number of postoperative complications is higher than the number of patients who suffer from postoperative complications; [b]Others: represent four severe complications (gastroparesis, lymphorrhagia, nerve problems, and pulmonary embolism) and two mild complications (gout and abdominal distension); [c]values are the number of patients and percentage of the total number

Risk factors of postoperative complications. Table 3 summarizes the factors related to complications arising after CRC surgery. In the univariate analysis, BMI (p=0.092), operation type (laparoscopy; p=0.023), sarcopenia (p=0.029), and hypoalbuminemia (p=0.010) were associated with the incidence of complications after CRC surgery. However, no significant differences were observed in terms of the gender, nutritional risk, operation time, anemia, type of resection, ASA grade, and the underlying diseases between the two groups. The results of the multivariate logistic regression analysis adjusted for potential confounders suggested that sarcopenia (p=0.045) and hypoalbuminemia (p=0.022) were the undesirable factors that were most markedly correlated with the incidence of complications after CRC surgery. In addition, laparoscopic surgery (p=0.042) emerged as a protective factor for CRC surgery.

Uni- and multivariate analyses of subgroups. In the subgroup for univariate analysis stratified by the tumor location, there were significant differences in terms of the BMI (p=0.020) and laparoscopic surgery (p=0.001) in the colon group (Table 4). Multivariate logistic regression analyses revealed that laparoscopic surgery (p=0.002, OR=0.312) was an independent factor affecting postoperative complications. However, in the rectum group (Table 5), we found that laparoscopic surgery (p=0.841) was not associated with

Table 3. Univariate and multivariate logistic regression analyses of factors associated with postoperative complications.

Factor	Univariate analysis				Multivariate analysis	
	Total (n=360)	Postoperative complications (n=113)	Non-postoperative complications (n=247)	p-value	OR (95% CI)	p-value
Gender				0.335		
Male	214	63	151			
Female	146	50	96			
ASA grade				0.638		
I	51	18	33			
II	248	74	174			
III	61	21	40			
NRS				0.297		
<3	193	56	137			
≥3	167	57	110			
BMI				0.092		
<18.5	36	17	19			
18.5–24.0	208	63	145			
>24.0	116	33	83			
Operating time				0.290		
>210 min	87	23	64			
≤210 min	273	90	183			
Prior abdominal surgery				0.884		
Yes	66	20	46			
No	294	93	201			
Charlson comorbidity index				0.911		
0	133	40	93			
1	151	49	102			
≥2	76	24	52			
Tumor location				0.463		
Rectum	146	49	97			
Colon	214	64	150			
Epidural anesthesia				0.388		
Yes	253	83	170			
No	107	30	77			
General anesthesia				0.435		
Yes	348	108	240			
No	12	5	7			
Laparoscopy				0.023*	0.595 (0.360–0.982)	0.042*
Yes	123	29	94			
No	237	84	153			
Combined resection				0.393		
Yes	20	8	12			
No	340	105	235			
TNM stage				0.908		
1–2	218	69	149			
3–4	142	44	98			
Sarcopenia				0.029*	1.606 (1.012–2.550)	0.045*
Yes	133	51	82			
No	227	62	165			
Hypoalbuminemia				0.010*	1.731 (1.082–2.771)	0.022*
Yes	119	48	71			
No	241	65	176			
Anemia				0.416		
Yes	92	32	60			
No	268	81	187			

ASA = American Society of Anesthesiology; BMI = body mass index; TNM = tumor-node-metastasis; NRS = nutritional risk screening; *statistically significant p<0.05

Table 4. Univariate and multivariate logistic regression analyses of factors associated with postoperative complications in colon.

Factor	Univariate analysis				Multivariate analysis	
	Total (n = 214)	Postoperative complications (n = 64)	No-postoperative complications (n = 150)	p-value	OR (95% CI)	p-value
Gender				0.160		
Male	116	30	86			
Female	98	34	64			
ASA grade				0.773		
I	29	10	19			
II	140	42	98			
III	45	12	33			
NRS				0.235		
<3	104	27	77			
≥3	110	37	73			
BMI				0.020*	0.765 (0.474–1.232)	0.270
<18.5	22	12	10			
18.5–24.0	117	29	88			
>24.0	75	23	52			
Operating time				0.466		
>210 min	44	11	33			
≤210 min	170	53	117			
Prior abdominal surgery				0.715		
Yes	45	12	33			
No	169	52	117			
Charlson comorbidity index				0.359		
0	74	18	56			
1	90	28	62			
≥2	50	18	32			
Epidural anesthesia				0.104		
Yes	65	14	51			
No	149	50	99			
General anesthesia				0.131		
Yes	205	59	146			
No	9	5	4			
Laparoscopy				0.001*	0.312 (0.151–0.647)	0.002*
Yes	71	11	60			
No	14.	52	90			
Combined resection				0.330		
Yes	9	4	5			
No	205	60	145			
TNM stage				0.447		
1–2	132	37	95			
3–4	82	27	55			
Sarcopenia				0.142		
Yes	81	29	52			
No	133	35	98			
Hypoalbuminemia				0.176		
Yes	79	28	51			
No	135	36	99			
Anemia				1.000		
Yes	72	21	51			
No	142	43	99			

ASA = American Society of Anesthesiology; BMI = body mass index; TNM = tumor-node-metastasis; NRS = nutritional risk screening; *statistically significant p<0.05

Table 5. Univariate and multivariate logistic regression analyses of factors associated with postoperative complications in rectum.

Factor	Univariate analysis				Multivariate analysis	
	Total (n=146)	Postoperative complications (n=49)	No-postoperative complications (n=97)	p-value	OR (95% CI)	p-value
Gender				1.000		
Male	98	33	65			
Female	48	16	32			
ASA grade				0.104		
I	22	8	14			
II	108	32	76			
III	16	9	7			
NRS				0.755		
<3	89	29	60			
≥3	57	20	37			
BMI				0.339		
<18.5	14	5	9			
18.5–24.0	91	34	57			
>24.0	41	10	31			
Operating time				0.443		
>210min	43	12	31			
≤210min	103	43	146			
Prior abdominal surgery				0.634		
Yes	21	8	13			
No	125	41	84			
Charlson comorbidity index				0.434		
0	59	22	37			
1	61	21	40			
≥2	26	6	20			
Epidural anesthesia				0.461		
Yes	42	15	26			
No	104	33	71			
General anesthesia				0.551		
Yes	143	49	94			
No	3	0	3			
Laparoscopy				0.841		
Yes	52	18	34			
No	94	31	63			
Combined resection				1.000		
Yes	11	4	7			
No	135	45	90			
TNM stage				0.290		
1–2	60	17	43			
3–4	86	32	54			
Sarcopenia				0.096	1.575 (0.754–3.290)	0.226
Yes	52	22	30			
No	94	27	67			
Hypoalbuminemia				0.010*	2.196 (0.996–4.844)	0.051
Yes	40	20	20			
No	106	29	77			
Anemia				0.029*	1970 (0.711–5458)	0.192
Yes	20	11	9			
No	126	38	88			

ASA = American Society of Anesthesiology; BMI = body mass index; TNM = tumor-node-metastasis; NRS = nutritional risk screening; *statistically significant p<0.05

postoperative complications. There were significant differences in terms of laparoscopic surgery as a factor affecting postoperative complications between the two subgroups.

Discussion

Sarcopenia is an age-related disease, as skeletal muscle mass and muscle function decline with age [24–26]. Prior research has established that elderly individuals with sarcopenia demonstrate a higher risk for long hospitalization and require long-term care compared to their non-sarcopenic peers [27]. Moreover, the pathogenesis of skeletal muscle depletion or sarcopenia involves multiple factors including altered nutrition status, chronic inflammatory state, changes in the endocrine environment, and so on [28]. In this study, we found that patients with sarcopenia demonstrated a lower BMI. A patient with remarkable weight loss may be linked to increased risks of aggravated primary disease, morbidity, and mortality [2, 29, 30]. Therefore, we believe that elderly CRC patients with sarcopenia have poor short-term outcomes after CRC surgery [15].

Our findings suggest that early actions should be considered for elderly patients with sarcopenia. The most important intervention is muscle exercise. Effective and reliable resistance exercises contribute toward improving their quality of life and outcomes, as they can maintain and enhance muscle mass and increase the protein content in skeletal muscle [31, 32]. Nutritional support is another key factor, as a change in diet may lead to better outcomes [32, 33]. Appropriate drugs can also be used for treating sarcopenia; however, no clinical studies have confirmed this [34]. In this study, we found that patients with postoperative complications had significantly longer hospital stays and incurred high hospitalization costs. This means that poor postoperative prognosis will increase the economic burden on the society and the families of patients. Therefore, more attention is needed on the adjustment of preoperative elderly sarcopenia patients. Through these measures, we can improve the health condition of elderly patients with sarcopenia before surgery, thereby reducing hospitalization time and costs [35].

Hypoalbuminemia is recognized to be associated with poor prognosis of malignancy [36–38]. Similarly, in this study, hypoalbuminemia was an independent risk factor for postoperative complications. Patients with hypoproteinemia have a higher incidence of postoperative complications. However, this effect is not related to age. For elderly patients, aging does not affect the incidence of hypoalbuminemia [39]. This may be because the reduction in food intake can result in hypoalbuminemia [40, 41]. Furthermore, chronic malnutrition resulting from complications can lead to persistent hypoalbuminemia in the elderly after surgery [42]. In contrast, hypoalbuminemia in elderly patients with CRC demonstrates an explicit relationship with inflammation [43]. During the post-operation acute inflammatory period, vascular permeability, and hepatic protein synthesis are weakened by the activation of reactive proteins [16]. In our opinion, it is imperative to improve the nutritional status of patients before surgery. At the same time, we recommend early enteral nutrition and intravenous supplementation of albumin in elderly patients with persistent hypoproteinemia after surgery [44].

In this study, we considered both open and laparoscopic surgeries. Compared to open surgery, we found that patients who underwent laparoscopic surgery experienced fewer postoperative complications. Therefore, we believe that laparoscopic surgery is beneficial for elderly patients. Most people believe that older people with pneumonia or cardiopulmonary complications are not suitable for laparoscopic surgery because a pneumoperitoneum with carbon dioxide can cause adverse pathophysiological changes (such as hypercapnia), reduce venous return, and increase airway pressure [45]. However, age is not a contraindication for laparoscopic surgery [46], as demonstrated by a lower rate of pneumonia and cardiopulmonary complications, as well as quicker recovery and greater scope for self-care, compared to open surgery [47, 48]. Furthermore, previous research has established that laparoscopic surgery has a protective effect on tumors in patients [49]. It demonstrates advantages in terms of reduced trauma and bleeding, less pain [50, 51], earlier restoration of bowel function, and earlier resumption of normal diet [52]. Therefore, laparoscopic surgery produces more favorable results as it reduces the incidence of postoperative complications in elderly patients relative to open surgery [50, 51]. In addition, for elderly people who need long-duration laparoscopic surgery, we suggest that sufficient preparation and effective management can reduce the risks and result in safer operations [53].

Overall, we found that laparoscopy is a protective factor for the patient. However, based on previous studies, tumors at different sites have different implications for laparoscopy [54, 55]; therefore, we performed the subgroup analysis. The single most striking observation was that laparoscopic surgery is not a protective factor for rectal cancer, and the effect of laparoscopic surgery on rectal cancer remains controversial. Some related studies have indicated that laparoscopic surgery exhibits a certain protective effect in terms of rectal cancer [56, 57]; however, our conclusion contradicts this finding. We detected no difference between laparoscopic and open surgeries in terms of postoperative complications for rectal surgery patients. Moreover, other studies have presented observations that support our conclusion [54].

This study suffered from several limitations. First, the experimental sample size was small. Hence, the process of data collection must be strengthened further to increase the sample size. Second, multicenter studies are needed to analyze whether the relationships identified are valid in other locations; our center is a single-center research institution. Third, we did not perform long-term survival analysis, and further study is needed to identify the long-term effects of sarcopenia on elderly CRC patients.

In conclusion, it was confirmed that sarcopenia is a risk factor associated with postoperative complications in elderly CRC patients. In addition, hypoalbuminemia was also identified as an undesirable factor markedly associated with elderly patients. We also found that laparoscopy is a protective factor for postoperative complications in CRC patients, especially for colon cancer patients. In summary, the treatment of sarcopenia and hypoproteinemia and the use of intraoperative laparoscopy can reduce the risks associated with CRC surgery.

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