

# Factors associated with postoperative complications and 1-year mortality after surgery for colorectal cancer in octogenarians and nonagenarians

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**Purpose:** To identify the factors affecting 30-day postoperative complications and 1-year mortality after surgery for colorectal cancer in octogenarians and nonagenarians.

**Methods:** Between 2005 and 2014, a total of 204 consecutive patients aged  $\geq 80$  years who underwent major colorectal surgery were included.

**Results:** One hundred patients were male (49%) and 52 patients had American Society of Anesthesiologists (ASA) score  $\geq 3$  (25%). Combined surgery was performed in 32 patients (16%). Postoperative complications within 30 days after surgery occurred in 54 patients (26%) and 30-day mortality occurred in five patients (2%). Independent risk factors affecting 30-day postoperative complications were older age ( $\geq 90$  years, hazard ratio [HR] with 95% confidence interval [CI] = 4.95 [1.69–14.47],  $P=0.004$ ), an ASA score  $\geq 3$  (HR with 95% CI = 4.19 [1.8–9.74],  $P=0.001$ ), performance of combined surgery (HR with 95% CI = 3.1 [1.13–8.46],  $P=0.028$ ), lower hemoglobin level ( $< 10$  g/dL, HR with 95% CI = 7.56 [3.07–18.63],  $P<0.001$ ), and lower albumin level ( $< 3.4$  g/dL, HR with 95% CI = 3.72 [1.43–9.69],  $P=0.007$ ). An ASA score  $\geq 3$  (HR with 95% CI = 2.72 [1.15–6.46],  $P=0.023$ ), tumor-node-metastasis (TNM) stage IV (HR with 95% CI = 3.47 [1.44–8.39],  $P=0.006$ ), and occurrence of postoperative complications (HR with 95% CI = 4.42 [1.39–14.09],  $P=0.012$ ) were significant prognostic factors for 1-year mortality.

**Conclusion:** Patient-related factors (older age, higher ASA score, presence of anemia, and lower serum albumin) and procedure-related factors (performance of combined surgical procedure) increased postoperative complications. Avoidance of 30-day postoperative complications may decrease 1-year mortality.

**Keywords:** colonic neoplasms, rectal neoplasms, laparoscopy, laparotomy, aged 80 years and above

## Introduction

According to the World Health Organization (WHO) reports, estimated life expectancy at age 60 years was 21.5 years in women and 18.5 years in men in 2012.<sup>1</sup> As the life expectancy increases, the population of the elderly is also increasing rapidly. Colorectal cancer is the third most common cancer in men and the second most common in women with 1,360,000 newly diagnosed patients worldwide.<sup>2</sup> Colorectal cancer has a higher incidence in older populations;<sup>3</sup> accordingly, colorectal surgeons have more frequently encountered octogenarian and nonagenarian patients with colorectal cancer in recent years.

Surgery is the primary treatment modality for colorectal cancer and is performed either with curative intent or for problem solving when patients present with colon perforation

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or obstruction. Chronological aging is closely related to impaired functional status due to medical comorbidities.<sup>4</sup> Although there is no consensus yet on whether chronological age adversely influences postoperative outcome, there are still concerns for operative safety in octogenarian and nonagenarian patients. To date, a number of studies have reported surgical outcomes in elderly patients; however, heterogeneous study populations complicate the interpretation of the results. Some studies include a variety of benign colorectal diseases in addition to colorectal cancer.<sup>5–8</sup> Diverse age cutoffs such as 65 years,<sup>9</sup> 70 years,<sup>10</sup> 75 years,<sup>11</sup> and 80 years<sup>12</sup> have also been used when defining elderly patients.

In octogenarian and nonagenarian patients, it is important to identify who would benefit from elective colorectal cancer resection. To date, there are few studies focusing on surgical outcomes in octogenarian and nonagenarian patients with colorectal cancer.<sup>13–16</sup> Moreover, there is only one population-based study investigating factors associated with 1-year mortality.<sup>13</sup> Thus, the primary objective of this study was to identify the factors affecting 30-day postoperative complications and 1-year mortality after surgery for colorectal cancer in octogenarians and nonagenarians.

## Methods

### Patients

Between 2005 and 2014, 204 consecutive patients aged  $\geq 80$  years who underwent major colorectal resection for colorectal cancer were included in the study. Eligibility criteria were histologically confirmed colorectal cancer and elective colectomy/proctectomy with or without metastasectomy. Patients undergoing nonresectional or bypass procedures or emergency operation for colorectal cancer were excluded. Patients were also excluded if they had histories of any type of previous abdominal malignancy. This retrospective clinical cohort study was performed at a university hospital according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines<sup>17</sup> and the principles expressed in the Declaration of Helsinki. All participants provided their written informed consent, and this study was approved by the Institutional Review Board of Wonju Severance Christian Hospital (YWMR-15-5-021).

### Study objectives

The primary objective was to identify the factors affecting 30-day postoperative complications and 1-year mortality after surgery for colorectal cancer in octogenarians and nonagenarians.

## Preoperative chemoradiation therapy, surgery, adjuvant therapy, and postoperative surveillance

Patients with rectal cancer who were diagnosed with clinical stage T3 or T4 and/or node-positive disease underwent preoperative chemoradiation therapy. A long course schedule included a total of 50.4 Gy of radiation and fluoropyrimidine-based chemotherapy.<sup>18,19</sup> Surgery was performed after standardized preoperative preparations.<sup>20</sup> Complete mesocolic excision for colon cancer and total mesorectal excision for rectal cancer were performed by two experienced colorectal surgeons. Overall treatment scheme, such as metastasectomy and chemotherapy, was decided on the basis of weekly, multidisciplinary team discussions.

After recovery from surgery, all patients with stage II, III, and IV disease were recommended to receive chemotherapy according to National Comprehensive Cancer Network (NCCN) guidelines.<sup>21</sup> Chemotherapy regimens included fluoropyrimidine (fluorouracil with folinic acid or capecitabine) alone or in combination with oxaliplatin (FOLFOX)/irinotecan (FOLFIRI). Targeted agents such as cetuximab and bevacizumab were used if indicated. Adjuvant radiation was used for patients with stage II and III rectal cancer. Radiation treatment consisted of 50.4 to 54 Gy of radiation dose in 28 to 30 fractions. All postoperative patients were registered in a dedicated colorectal database and followed at 3- or 6-month intervals for the first 5 years and then yearly thereafter. Patients in this study were followed until death or September 30, 2014.

### Outcome variables

Patient's age at the time of admission was calculated based on the birth date. Octogenarian refers to a patient who is 80 to 89 years old, and nonagenarian to a patient who is 90 to 99 years old. Postoperative surgical complications were defined as the events that required additional treatment within 30 days after surgery. Severity of surgical complications was evaluated based on the Clavien–Dindo classification.<sup>22</sup> One-year mortality was defined as the all-cause deaths that occurred within 1 year after surgery. Length of hospital stay was defined as the number of nights from the date of surgery to discharge. Conversion to open surgery was defined as the completion of planned surgical procedures using a conventional laparotomy incision. Outcome variables such as intensive care unit (ICU) care or blood transfusions were included if they were required within 48 hours after index surgery.

Binary cutoffs of continuous variables such as operative time, blood loss, hemoglobin, and albumin level were decided based on the published literature.<sup>23–26</sup> Long operative time ( $\geq 300$  minutes),<sup>23</sup> greater blood loss ( $\geq 150$  mL),<sup>24</sup> and moderate-to-severe anemia (Hb  $< 10$  g/dL)<sup>25</sup> were associated with higher risk of postoperative complications following colorectal surgery. Lower albumin level (3.4 g/dL)<sup>26</sup> was associated with poor oncologic outcomes in colorectal cancer patients.

## Statistical analysis

All statistical analyses were performed with IBM SPSS Statistics for Windows, version 21.0 (IBM Corporation, Armonk, NY, USA) and MedCalc Statistical Software version 15.2.2 (MedCalc Software bvba, Ostend, Belgium). Categorical variables were described by frequencies and percentages and compared using chi-square test or Fisher's exact test as appropriate. Continuous variables were described as mean and standard deviation and analyzed by Student's *t*-test. Factors associated with 30-day complications were assessed by logistic regression analysis. Factors associated with 1-year mortality were analyzed by Cox proportional hazard model. A *P*-value  $< 0.05$  was considered statistically significant.

Univariable logistic regression analysis was performed with all variables, and variables with a *P*-value  $< 0.05$  (age, American Society of Anesthesiologists [ASA] score, laparoscopy, combined surgery, hemoglobin, and albumin) were used for multivariable analysis. Tumor location was also used for analysis, as rectal cancer surgery is a well-known risk factor for postoperative complications.<sup>27</sup> Multivariable logistic regression analysis was performed by forward stepwise selection of variables. Univariable Cox proportional hazard model analysis was performed with all variables, and variables with a *P*-value  $< 0.05$  (ASA score, pathological tumor-node-metastasis [pTNM], and 30-day complication) were adopted for multivariable analysis. In addition, age and tumor location were used for analysis as older age and rectal cancer were well-known risk factors for unfavorable survival.<sup>21,28</sup> Multivariable Cox proportional hazard model analysis was performed by forward stepwise selection of variables.

## Results

### Patient characteristics

Mean age was 84 ( $\pm 4$ ) years (range: 80 to 99 years). The total of 204 patients consisted of patients aged 80 to 89 years ( $n=181$ , 89%) and patients over 90 years ( $n=23$ , 11%). One hundred patients were male (49%), and 52 patients had

an ASA score  $\geq 3$  (25%). Fifty-five patients had multiple comorbidities (27%). In terms of tumor location, 110 patients had colon cancer (54%), and 94 patients had rectal cancer (46%). Open surgery was performed in 80 patients (39%), and laparoscopy was performed in 124 (61%). Conversion to open surgery occurred in ten patients (8.1%). Among the 29 patients with TNM stage IV disease, nine underwent metastasectomy including liver ( $n=6$ , 2.9%), vagina wall ( $n=2$ , 1.0%), and bladder ( $n=1$ , 0.5%). Laboratory tests at the time of initial diagnosis showed that mean hemoglobin (Hb) level was 11.7 ( $\pm 2.2$ ) g/dL and mean albumin level was 3.9 ( $\pm 0.4$ ) g/dL. Detailed patient characteristics are presented in Tables 1 and 2.

Median follow-up duration was 23.3 months (range: 0.1–118.7 months). Fifty-seven patients (27.9%) had  $< 1$ -year of follow-up. Eight patients were lost to follow-up, and all were confirmed dead based on the national health insurance service data. However, the exact reasons for death were not identified in the lost follow-up patients.

### Details of combined surgeries

Combined surgery was performed in 32 patients (16%). Liver resection was most common ( $n=7$ , 3.4%) followed by uterus ( $n=6$ , 2.9%), colon ( $n=4$ , 2.0%), ovary ( $n=4$ ), and gastric resection ( $n=4$ ).

### Short-term outcomes

Mean operative time was 188 ( $\pm 77$ ) minutes, and mean intraoperative blood loss was 127 ( $\pm 204$ ) mL. Postoperative complication within 30 days after surgery occurred in 54 patients (26%) and 30-day mortality occurred in five patients (2%). Specifically, pulmonary complication was most common ( $n=17$ ), followed by wound ( $n=15$ ) and anastomotic complications ( $n=6$ ). ICU care was required in 94 (46%), and blood transfusion was done in 72 (35%) patients. Mean time to soft diet was 6 ( $\pm 3$ ) days, and mean length of hospital stay was 14 ( $\pm 10$ ) days (Table 3).

### Factors associated with 30-day postoperative complications

Based on multivariable logistic regression analysis, independent risk factors affecting 30-day postoperative complications were older age ( $\geq 90$  years, hazard ratio [HR] with 95% confidence interval [CI] =4.95 [1.69–14.47],  $P=0.004$ ), an ASA score  $\geq 3$  (HR with 95% CI =4.19 [1.8–9.74],  $P=0.001$ ), performance of combined surgery (HR with 95% CI =3.1 [1.13–8.46],  $P=0.028$ ), lower hemoglobin level ( $< 10$  g/dL, HR with 95% CI =7.56

**Table 1** Patient characteristics (n=204)

Variables	N (%) or mean ( $\pm$ SD)
Age (continuous) (years)	84 ( $\pm$ 4)
Age (binary)	
80–89 years old	181 (89%)
90–99 years old	23 (11%)
Sex	
Male	100 (49%)
Body mass index (kg/m <sup>2</sup> )	23 ( $\pm$ 4)
ASA score ( $\geq$ 3)	52 (25%)
Comorbidity	
Diabetes	42 (21%)
Cardiac disease	123 (60%)
Pulmonary disease	31 (15%)
Kidney disease	2 (1%)
Liver disease	5 (2%)
Two or more comorbidities	55 (27%)
Preoperative chemoradiation (+)	8 (4%)
Tumor location	
Colon	110 (54%)
Rectum	94 (46%)
Types of operation	
Abdominoperineal resection, Hartmann	24 (12%)
Low anterior resection	75 (37%)
Left colectomy	48 (24%)
Subtotal colectomy	5 (2%)
Right colectomy	47 (23%)
Other	5 (2%)
Surgical approach	
Open surgery	80 (39%)
Laparoscopy	124 (61%)
Conversion to open surgery (+)	10 (8.1%)
Metastasectomy (–) and organs	
Liver	9 (4.4%)
Lung	5 (2.5%)
Peritoneum	3 (1.5%)
Bone	2 (1.0%)
Lung, liver, and bone	1 (0.5%)
Metastasectomy (+) and organs	
Liver	6 (2.9%)
Vagina wall	2 (1.0%)
Bladder	1 (0.5%)

**Abbreviations:** SD, standard deviation; ASA, American Society of Anesthesiologists.

[3.07–18.63],  $P < 0.001$ ), and lower albumin level ( $< 3.4$  g/dL, HR with 95% CI = 3.72 [1.43–9.69],  $P = 0.007$ ). Rectal primary tumor (HR with 95% CI = 2.22 [0.97–5.04],  $P = 0.058$ ) and the use of laparoscopy (HR with 95% CI = 0.77 [0.35–1.7],  $P = 0.518$ ) were not independent risk factors for postoperative complications (Table 4).

## Factors associated with 1-year mortality

Based on multivariable Cox proportional hazard model analysis, an ASA score  $\geq 3$  (HR with 95% CI = 2.72 [1.15–6.46],  $P = 0.023$ ), TNM stage IV (HR with 95% CI = 3.47 [1.44–8.39],  $P = 0.006$ ), and occurrence of postoperative complications (HR with 95% CI = 4.42 [1.39–14.09],

**Table 2** Pathological and laboratory data (n=204)

Variables	N (%) or mean ( $\pm$ SD)
pTNM	
I	35 (17%)
II	66 (32%)
III	74 (36%)
IV	29 (14%)
Retrieved lymph nodes (number)	20 ( $\pm$ 9)
Histologic grade	
G3, other	20 (10%)
Tumor size (cm)	5 ( $\pm$ 2)
Laboratory data <sup>a</sup> (reference value)	
White blood cell count (4.0–10.0) (E9/L)	7.5 ( $\pm$ 3.1)
Hemoglobin (13.5–17.0) (g/dL)	11.7 ( $\pm$ 2.2)
Platelet (165–360) (E9/L)	299 ( $\pm$ 112)
Neutrophil (1.8–7.5) (E9/L)	5 ( $\pm$ 3)
Lymphocyte (1.0–2.8) (E9/L)	1.7 ( $\pm$ 0.7)
C-reactive protein ( $< 0.30$ ) (mg/dL)	1.7 ( $\pm$ 3.2)
Albumin (3.2–5.5) (g/dL)	3.9 ( $\pm$ 0.4)

**Note:** <sup>a</sup>Values at the time of initial diagnosis.

**Abbreviations:** SD, standard deviation; pTNM, pathological tumor-node-metastasis.

$P = 0.012$ ) were significant prognostic factors for 1-year mortality. Age  $\geq 90$  years (HR with 95% CI = 0.23 [0.05–1.03],  $P = 0.054$ ) and rectal primary cancer (HR with 95% CI = 1.09 [0.39–3.06],  $P = 0.873$ ) did not influence 1-year mortality significantly (Table 5).

**Table 3** Short-term outcomes (n=204)

Variables	N (%) or mean ( $\pm$ SD)
Operative time (minutes)	188 ( $\pm$ 77)
Estimated blood loss (mL)	127 ( $\pm$ 204)
30-day complication (+)	54 (26%)
30-day mortality (+)	5 (2%)
Clavien–Dindo score $\geq 3$	22 (11%)
Type of complication <sup>a</sup>	
Pulmonary	17
Wound	15
Leakage	6
Urinary	5
Bleeding	5
Cardiac	4
Ileus	3
Other	6
Intensive care unit admission (+)	94 (46%)
Blood transfusion (+)	72 (35%)
Time to soft diet (days)	6 ( $\pm$ 3)
Hospital stay (days)	14 ( $\pm$ 10)
Postoperative chemotherapy (+)	82 (40%)
Chemotherapy regimen	
Fluoropyrimidine	75 (37%)
FOLFOX	5 (2%)
FOLFIRI	2 (1%)
Time to chemotherapy initiation (days)	38 ( $\pm$ 10)

**Note:** <sup>a</sup>Eight of 204 patients (3.9%) had more than one type of complication.

**Abbreviations:** SD, standard deviation; FOLFOX, folinic acid, fluorouracil, oxaliplatin; FOLFIRI, folinic acid, fluorouracil, irinotecan.

**Table 4** Factors associated with 30-day postoperative complications in logistic regression analysis (n=204)

Variables	Univariable		Multivariable	
	HR (95% CI)	P-value	HR (95% CI)	P-value
Age (years)				
≥90 vs <90	4.44 (1.81–10.86)	0.001	4.95 (1.69–14.47)	0.004
Sex				
Male	1.17 (0.63–2.17)	0.627	NA	
ASA score				
≥3	4.43 (2.24–8.75)	<0.001	4.19 (1.8–9.74)	0.001
BMI (kg/m <sup>2</sup> )				
≥30	1.2 (0.3–4.82)	0.796	NA	
Tumor location				
Rectum	1.01 (0.54–1.89)	0.970	2.22 (0.97–5.04)	0.058
Laparoscopy				
(+)	0.49 (0.26–0.93)	0.028	0.77 (0.35–1.7)	0.518
Combined surgery				
(+)	3.01 (1.38–6.57)	0.006	3.1 (1.13–8.46)	0.028
Operative time (minutes)				
≥300	1.3 (0.38–4.44)	0.672	NA	
Blood loss (mL)				
≥150	1.22 (0.52–2.86)	0.653	NA	
Hemoglobin (g/dL) <sup>a</sup>				
≥10 vs <10	6.21 (2.94–13.13)	<0.001	7.56 (3.07–18.63)	<0.001
Albumin (g/dL) <sup>a</sup>				
≥3.4 vs <3.4	4.5 (2.07–9.79)	<0.001	3.72 (1.43–9.69)	0.007

**Note:** <sup>a</sup>Values at the time of initial diagnosis.

**Abbreviations:** HR, hazard ratio; CI, confidence interval; NA, not applied; ASA, American Society of Anesthesiologists; BMI, body mass index.

**Table 5** Factors associated with 1-year mortality in Cox proportional hazard model (n=204)

Variables	Univariable		Multivariable	
	HR (95% CI)	P-value	HR (95% CI)	P-value
Age (years)				
≥90 vs <90	1.5 (0.35–6.35)	0.581	0.23 (0.05–1.03)	0.054
Sex				
Male	1.75 (0.78–3.92)	0.175	NA	
ASA score				
≥3	2.31 (1.06–5.04)	0.035	2.72 (1.15–6.46)	0.023
BMI (kg/m <sup>2</sup> )				
≥30	1.41 (0.19–10.4)	0.737	NA	
Tumor location				
Rectum	1.35 (0.62–2.91)	0.450	1.09 (0.39–3.06)	0.873
pTNM				
IV vs I, II, III	4.15 (1.88–9.15)	<0.001	3.47 (1.44–8.39)	0.006
Laparoscopy				
(+)	0.47 (0.22–1.02)	0.056	NA	
Hemoglobin (g/dL) <sup>a</sup>				
<10 vs ≥10	1.68 (0.7–3.99)	0.243	NA	
Albumin (g/dL) <sup>a</sup>				
<3.4 vs ≥3.4	1.28 (0.48–3.4)	0.619	NA	
30-day complication				
(+)	3.63 (1.68–7.85)	0.001	4.42 (1.39–14.09)	0.012

**Note:** <sup>a</sup>Values at the time of initial diagnosis.

**Abbreviations:** HR, hazard ratio; CI, confidence interval; NA, not applied; ASA, American Society of Anesthesiologists; BMI, body mass index; pTNM, pathological tumor-node-metastasis.



## Discussion

The major findings of this study were that multiple risk factors were associated with 30-day postoperative complications such as advanced chronological age (aged  $\geq 90$  years), poor functional status (ASA score  $\geq 3$ ), invasiveness of surgical procedure (performance of combined surgery), presence of anemia (Hb  $< 10$  g/dL), and poor nutritional status (albumin  $< 3.4$  g/dL). To prevent the postoperative complications, the surgeon and the surgical team should consider multidimensional aspects preoperatively. Adverse prognostic factors affecting 1-year mortality were poor functional status (ASA score  $\geq 3$ ), advanced disease stage (TNM stage IV), and occurrence of 30-day postoperative complications. To decrease 1-year mortality, avoidance of postoperative complications and careful patient selection by considering preoperative clinical features (ASA score  $\geq 3$  and TNM stage IV) are important.

There is paucity in literature concerning surgical outcomes after colorectal cancer surgery in octogenarians and nonagenarians (Table 6). Colon and rectal cancer surgeries characterized by complete mesocolic excision<sup>29</sup> and total mesorectal excision<sup>30</sup> are quite different from surgery for benign colorectal diseases. Emergency surgery carries higher risk of postoperative morbidity and mortality.<sup>31</sup> Accordingly, in this era of an aging society, it is important to investigate surgical outcomes in octogenarian and nonagenarian patients. To the best of our knowledge, this is the second largest study<sup>13</sup> investigating octogenarian and nonagenarian patients undergoing elective surgery for colorectal cancer.

## Factors associated with 30-day postoperative complications

Various factors were associated with the occurrence of postoperative complications in octogenarian and nonagenarian patients. Previous studies reported postoperative complication rates of 12% to 27.5% after colorectal cancer surgery in octogenarians and nonagenarians,<sup>14–16</sup> and the rate in this study was 26%. The aging process diminishes physiologic functional reserves in vital organs; therefore, chronological age itself is an established risk factor. Turrentine et al<sup>32</sup> investigated 7,696 patients undergoing major general and vascular surgical procedures and observed that the postoperative morbidity rate was 49% in octogenarians and 61% in nonagenarians. Similar findings were obtained in this study (22.7% postoperative complication rate in octogenarians and 56.5% in nonagenarians). Patient functional status and comorbidity are important factors when considering surgery. The ASA score is a widely adopted classification that indicates severity

**Table 6** Literature review regarding colorectal cancer operations in patients aged  $\geq 80$  years

Authors	N	Location	Emergency	ASA $\geq 3$ (%)	OT (minutes)	Conv (%)	Diet (days)	LOS (days)	Cx (%)	AL (%)	Mortality (%)	Comments
Vignali et al <sup>16</sup>	O: 61 L: 61	Colon, rectum	Excluded	O: 2.6 <sup>a</sup> L: 2.5 <sup>a</sup>	O: 171 L: 220*	6.1	O: 5.9 L: 4.8 <sup>b*</sup>	O: 12.9 L: 9.8*	O: 31.1 L: 21.5	O: 5 L: 7	O: 3.3 L: 1.6	Case-matched series
Gurevitch et al <sup>15</sup>	40	Right colon	Included	23	NR	NR	NR	7.5	27.5	NR	10	
Kunitake et al <sup>13</sup>	26,108 (Cancer Registry)	Colon, rectum	Included	NR	NR	NR	NR	10.6–12.4 (colon) 11.4–12.6 (rectum)	NR	NR	6	One-year mortality
Chaudhary et al <sup>14</sup>	173	Colon, rectum	NR	42	NR	7.5	NR	5	12	1.2	1.7	Short-term outcomes
Current study	204	Colon, rectum	Excluded	25	188	8.1	6	14	26	2.5	2	

**Notes:** \* $p < 0.05$ ; <sup>a</sup>mean; <sup>b</sup>return to bowel function.

**Abbreviations:** ASA, American Society of Anesthesiologists score; OT, operative time; Conv, conversion to open surgery; Diet, time to diet; LOS, length of stay; Cx, postoperative complication; L, laparoscopy; O, open surgery; NR, not reported; AL, anastomotic leakage.

of systemic illness. Previous studies investigating colorectal cancer surgery in octogenarians and nonagenarians included 23%<sup>15</sup> and 42%<sup>14</sup> of patients with ASA score  $\geq 3$  and this study included 25%. Higher ASA score has been reported as a significant predictor for postoperative morbidity and mortality,<sup>33</sup> and we also observed that ASA score  $\geq 3$  was an independent risk factor for postoperative complications. Invasiveness of the surgical procedure is also related to postoperative morbidity. Octogenarian patients undergoing major resections for lung, esophageal, and pancreas cancer showed different postoperative morbidity rates according to the type of surgeries.<sup>34</sup> The impact of combined surgery on surgical outcomes has not been reported in octogenarians.<sup>5-16</sup> In this study, combined surgery was performed in 16% of patients and included liver, uterus, or colon resection; combined surgery was found to be an independent risk factor for complications. Anemia is a frequent clinical feature of colorectal malignancy and is closely related to older age and comorbidities.<sup>35</sup> Patients with anemia are susceptible to nosocomial infections and adverse postoperative events.<sup>25</sup> In this study, 19% of patients had Hb  $< 10$  g/dL, and the postoperative complication rate was 19% in Hb  $\geq 10$  g/dL group and 59% in Hb  $< 10$  group. Serum albumin level indicates patient's nutritional status and elderly patients are at particular risk of poor nutritional status. Low albumin level correlates with the occurrence of postoperative complications<sup>36</sup> as was confirmed in our study. In this study, 16% of patients had albumin  $\leq 3.4$  g/dL, and the postoperative complication rate was 21% in albumin  $> 3.4$  g/dL group and 55% in albumin  $\leq 3.4$  g/dL group.

### Factors associated with 1-year mortality

ASA score  $\geq 3$ , TNM stage IV, and occurrence of postoperative complications were unfavorable risk factors for 1-year mortality in this study. Higher ASA score<sup>37</sup> and advanced TNM stage<sup>38</sup> are well-known prognostic factors. The presence of postoperative complications delays patient recovery and worsens oncologic outcomes.<sup>39</sup> The exact mechanism is unclear, but omission of adjuvant treatment or direct impairment of physical status such as heart failure due to complication severity has been suggested as potential causes for poor survival.<sup>40</sup> Thus, surgeons should be aware of the negative impact of postoperative complications on 1-year mortality. A high proportion of patients (40%) underwent adjuvant chemotherapy. In our institution, patients were discussed at weekly multidisciplinary team meetings and adjuvant treatment was based on NCCN guidelines. If performance status was acceptable, we actively encouraged adjuvant treatment.

### Limitations

This study has limitations in the retrospective study design and small sample size from a single institution. These factors might diminish the statistical power of the study and compromise the generalizability of the current findings. In the octogenarian patient group, 41 patients (23%) had ASA score  $\geq 3$ ; on the other hand, eleven patients (48%) had ASA score  $\geq 3$  in the nonagenarian group. However, there were only 23 nonagenarian patients, comprising 11% of the study population. Accordingly, we could not draw definitive conclusions from our small study sample. Also, due to the large time span of this study, some treatment-related factors changed during the study period. For example, laparoscopy has been popularized and a fast-track protocol has been selectively adopted. However, we could not consider all these factors in the current analysis due to the small study size. Finally, the retrospective nature of the study does not allow us to specify whether the cause of death is cancer related or not. However, this is the second largest series to investigate surgical outcomes in octogenarian and nonagenarian patients with colorectal cancer.

### Conclusion

In summary, this study identified various factors affecting 30-day postoperative complications and 1-year mortality after surgery for colorectal cancer in octogenarians and nonagenarians. To prevent postoperative complications, multidimensional aspects should be considered preoperatively, including chronological age, physical functional status based on ASA score, whether to perform combined surgical procedure, presence of anemia, and nutritional status based on serum albumin level. Inherent preoperative features such as ASA score  $\geq 3$  and TNM stage IV negatively influenced 1-year mortality. However, our results suggest that avoidance of 30-day postoperative complications may decrease 1-year mortality; thus, surgeons should focus on meticulous surgical technique and comprehensive postoperative care. In the future, a prospective study with a larger cohort would be helpful to confirm the current findings of this study.

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### Author contributions

YWK conceived and designed the experiments, performed the experiments, and analyzed the data. IYK and YWK contributed reagents/materials/analysis tools and YWK wrote the

paper. All authors contributed toward data analysis, drafting and critically revising the paper and agree to be accountable for all aspects of the work.

## Disclosure

The authors report no conflicts of interest in this work.

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