Impact of severe postoperative complications on the prognosis of older patients with colorectal cancer: a two-center retrospective study

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Abstract

Background The occurrence of postoperative complications may affect short-term outcomes and prognosis of patients with various malignancies. However, the prognostic impact of these complications in older patients with colorectal cancer (CRC) remains unclear. Therefore, this study aimed to investigate the impact of severe postoperative complications on the oncological outcomes of older (aged ≥ 80 years) and non-older (aged < 80 years) patients with CRC.

Methods We retrospectively analyzed 760 patients with stage I–III CRC who underwent curative surgery in two institutions between 2013 and 2019. The patients were categorized into older (aged ≥ 80 years, 191 patients) and non-older (aged < 80 years, 569 patients) groups. Short- and long-term outcomes were compared between the two groups.

Results The incidence of severe postoperative complications did not differ between the two groups ($p = 0.981$). Cancer-specific survival (CSS) was significantly worse in older patients with severe complications than in those without severe complications ($p = 0.007$); meanwhile, CSS did not differ between the non-older patients with severe complications and those without severe complications. Survival analysis revealed that the occurrence of severe postoperative complications was an independent prognostic factor for CSS in older patients (hazard ratio = 4.00, 95% confidence interval: 1.27–12.6, $p = 0.017$).

Conclusion CRC surgery can be safely performed in older and non-older patients. Moreover, the occurrence of severe postoperative complications might more strongly affect the prognosis of older patients than that of non-older patients.

Keywords Colorectal cancer, Older patients, Severe postoperative complication, Minimally invasive surgery

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Background

Colorectal cancer (CRC) had the third highest incidence rate (over 900,000 new cases globally) and the second highest cancer-related mortality rate in 2020 [1]. Prolonged life expectancy has led to the increasing incidence of CRC in older patients, with 25% of individuals with CRC being diagnosed at the age of ≥80 years [2]. Owing to the increased number of older patients who undergo surgery for CRC and the prolonged life expectancy of older individuals, the prognostic predictors of CRC in older patients should be elucidated.

Generally, older patients have more comorbidities that may affect their postoperative course. The occurrence of postoperative complications can impair the quality of life and be associated with mortality. Therefore, postoperative morbidity and mortality rates are higher in older patients [3, 4]. Nevertheless, recent studies have demonstrated the technical and oncological safety of laparoscopic surgery in older patients [5, 6]. However, the occurrence of postoperative complications could affect not only the short-term outcomes but also the prognosis in patients with various malignancies [7–9]. The prognostic impact of these complications in older patients with CRC remains unclear.

Therefore, this study aimed to evaluate the short- and long-term outcomes in older patients with CRC. Moreover, whether the postoperative complications affect the prognosis in patients aged ≥80 years with CRC was investigated using the cancer-specific survival (CSS) rate, and the results were compared with those in non-older patients.

Methods

Patients

We retrospectively analyzed 763 patients with pathological stage (pStage) I–III CRC who underwent curative surgery in two institutions between 2013 and 2019. Three patients, aged 77, 85, and 88 years, who died during their hospital stay were excluded. Hence, only 760 patients were included in this study. Of the total patients, 660 and 100 were treated in Hospitals 1 and 2, respectively. The patients were categorized into the older (aged ≥80 years, $n=191$) and non-older (aged <80 years, $n=569$) groups. Their characteristics, pathological and surgical findings, and postoperative clinical courses were reviewed retrospectively from the medical records and databases of our institutions. The preoperative diagnosis of colorectal adenocarcinoma was confirmed through endoscopy, followed by biopsy. Colorectomy and lymph node dissection were performed in accordance with the Japanese Society for Cancer of the Colon and Rectum [10]. Tumor staging was performed based on the 8th Union for International Cancer Control staging system [11]. The macroscopic and histological types were determined according

to the Japanese classification of colorectal carcinoma, 9th edition [12]. Follow-up procedures were performed every 3–6 months for 2 years postoperatively and continued for at least 5 years.

Evaluation of postoperative complication

The presence and severity of postoperative complications were evaluated using the Clavien–Dindo classification; severe complications were defined as grade III or higher overall complications [13, 14].

Statistical analyses

The continuous variables were expressed as the mean ± standard deviation. The categorical variables between the two groups were compared using the chi-square test. The survival curves for overall survival (OS), CSS, and estimated cumulative incidence of recurrence were derived using the Kaplan–Meier method and compared using the log-rank test. CSS was defined as the time between the date of surgery and date of death from CRC. To analyze the impact of complications on prognosis of CRC and minimize the effect of early deaths that resulted from postoperative complications, patients who died during their hospital stay were excluded from survival analysis. Multivariate survival analysis was performed using the Cox proportional hazard regression model to identify the independent prognostic factors for CSS. The propensity score of each patient was assessed using a logistic regression model to control confounding factors for the occurrence of severe postoperative complications and prognosis. The covariates included sex (male or female), body mass index (>22 or ≤22 kg/m^2), American Society of Anesthesiologists (ASA) Physical Status (1–2 or ≥3), tumor location (right-/left-sided colon/rectum), treatment for obstruction (present or absent), histopathological type (tub and pap/por and muc), pathological T stage (T1-3 or T4) and N status (N0 or N1-2), stoma (permanent/diverting/absent), surgical approach (open or laparoscopic), and adjuvant chemotherapy (present or absent). Patients in the non-older and older groups were matched in a 1:1 ratio using the nearest propensity score on the logit scale. Statistical significance was set at $p < 0.05$. The JMP 16.1 statistical software for Macintosh (SAS Institute, Cary, NC, USA) was used to perform all analyses.

Results

Comparison of clinicopathological factors between the non-older and older groups

Table 1 presents the clinicopathological characteristics of the patients. Table 2 shows the association between age and clinicopathological factors. The mean age was 67.9 ± 8.49 years in the non-older group and 83.8 ± 3.40 years in the older group ($P < 0.001$). Older age (≥80 years)

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Table 1 Patient characteristics

Variables		Total patients (n=760)	
Age, years		71.9	±10.2
Sex	Female	331	(44%)
	Male	429	(56%)
BMI, kg/m²		22.2	±3.56
ASA-PS	4	6	(1%)
	3	147	(19%)
	2	516	(68%)
	1	91	(12%)
Treatment for colorectal obstruction	Presence	48	(6%)
	Absence	712	(94%)
Location	Right	273	(36%)
	Left	236	(31%)
	Rectum	251	(33%)
Preoperative treatment (chemo-radio or chemo therapy)	Presence	11	(1%)
	Absence	749	(99%)
Histopathological type[a]	por/sig/muc	62	(8%)
	tub/pap	698	(92%)
T stage[b]	T4	138	(18%)
	T3	377	(50%)
	T2	115	(15%)
	T1	130	(17%)
N stage[b]	N2	85	(11%)
	N1	199	(26%)
	N0	476	(63%)
pStage[b]	3	284	(37%)
	2	273	(36%)
	1	203	(27%)
Lymphatic invasion	Presence	483	(64%)
	Absence	277	(36%)
Venous invasion	Presence	420	(55%)
	Absence	340	(45%)
Surgical approach	Open	226	(30%)
	Laparoscopic	534	(70%)
Operative blood loss, ml		139	±281
Operative time, min		269	±109
Severe postoperative complication[c]	Presence	56	(7%)
	Absence	704	(93%)
Adjuvant chemotherapy	Presence	230	(30%)
	Absence	530	(70%)

a: According to the Japanese classification of colorectal carcinoma, 8th edition

b: According to the 7th edition of the UICC/TNM staging system

c: Grade 3 or higher according to the Clavien–Dindo classification

tub tubular adenocarcinoma, *pap* papillary adenocarcinoma, *por* poorly differentiated adenocarcinoma,

sig signet-ring cell carcinoma, *muc* mucinous adenocarcinoma, *ASA-PS* American Society of Anesthesiologists Physical Status, *BMI* body mass index

was significantly associated with female sex (p=0.019), high ASA score ($\geq$3, p<0.001), lower preoperative serum albumin level ($\leq$3.5 g/dL, p=0.001), higher incidence of right-sided colon cancer (p=0.005), poor differentiated histopathological type (p=0.049), advanced pStage (stage II or III: p=0.013), lymphatic invasion (p=0.018), open surgery (p=0.005), shorter operative time (p=0.008), lower frequency of adjuvant chemotherapy (p<0.001), and longer postoperative hospitalization (p=0.041). The

frequency of preoperative chemo-radio or chemotherapy and the proportions of elective and urgent surgery did not differ between the non-older and older groups. No significant difference was found in stoma creation, whereas the surgical procedure differed between the two groups. The incidence of severe postoperative complications did not differ between the two groups (p=0.981). Details of the postoperative complications are presented in Additional file 1. No significant between-group differences were observed in the occurrence of any complications except for anastomotic leakage.

Survival analysis

The median postoperative follow-up duration was 49.4 and 40.8 months in the non-older and older patients, respectively. The older group showed significantly worse 5-year OS (69.8 vs. 85.9%; p<0.001) and CSS (82.5% vs. 90.3%; p=0.047) than the non-older group (Fig. 1).

Table 3 shows the associations between CSS and clinicopathological factors in 760 patients. The univariate and multivariate analyses revealed that high ASA score ($\geq$3; hazard ratio [HR]=2.47, 95% confidence interval [CI]: 1.45–4.20, p<0.001), rectal cancer (HR=2.10, 95% CI: 1.26–3.50, p=0.004), deeper tumor invasion (pathological T4; HR=3.19, 95% CI: 1.83–5.55, p<0.001), and lymph node metastasis (pathological N1–2; HR=2.99, 95% CI: 1.67–5.35, p<0.001) were independent prognostic factors for CSS. In contrast, older age and postoperative complications were not prognostic factors for CSS.

Prognostic impact of postoperative complications in elderly patients

Figure 2 shows the results of the survival analyses stratified based on age. The occurrence of complications did not affect the prognosis in the non-older group (Fig. 2a and b); in the older group, OS (p=0.021; Fig. 2c) and CSS (p=0.007; Fig. 2d) were significantly worse in patients with complications than in those without complications. Moreover, the correlation between the estimated cumulative recurrence rate and postoperative complications was analyzed (Additional file 2). The recurrence rates did not differ between patients with and without severe complications in the non-older group (17.6 vs. 25.6%; p=0.371, Additional file 2a); meanwhile, the recurrence rates tended to be higher in patients with complications than in those without complications in the older group (17.4% vs. 35.1%; p=0.113, Additional file 2b).

Table 4 shows the prognostic factors for CSS in older patients. The univariate and multivariate analyses revealed that deeper tumor invasion (pathological T4; HR=4.12, 95% CI: 1.73–9.83, p=0.001), lymph node metastasis (pathological N1–2; HR=3.25, 95% CI: 1.25–8.40, p=0.014), and postoperative complications (HR=4.00, 95% CI: 1.27–12.6, p=0.017) were

Table 2 Comparison of clinicopathological factors between non-older and older patients

		n = 760	Non-older group *n* = 569		Older group *n* = 191		*P*-value [d]
Age, years			67.9	± 8.49	83.8	± 3.40	< 0.001
Sex	Female	331	234	(41%)	97	(51%)	0.019
	Male	429	335	(59%)	94	(49%)	
BMI, kg/m^2	> 22	389	302	(53%)	87	(46%)	0.071
	≤ 22	371	267	(47%)	104	(54%)	
ASA-PS	≥ 3	153	92	(16%)	61	(32%)	< 0.001
	< 3	607	477	(84%)	130	(68%)	
Preoperative albumin level, g/dl	≤ 3.5	159	103	(18%)	56	(29%)	0.001
	> 3.5	601	466	(82%)	135	(71%)	
Location	Right	273	186	(33%)	87	(45%)	0.005
	Left	236	187	(33%)	49	(26%)	
	Rectum	251	196	(34%)	55	(29%)	
Preoperative treatment (chemo-radio or chemo therapy)	Presence	11	9	(2%)	2	(1%)	0.592
	Absence	749	560	(98%)	189	(99%)	
Treatment for colorectal obstruction	Presence	48	33	(6%)	15	(8%)	0.312
	Absence	712	536	(94%)	176	(92%)	
Histopathological type[a]	por/sig/muc	62	40	(7%)	22	(12%)	0.049
	tub/pap	698	529	(93%)	169	(88%)	
T stage[b]	T4	138	107	(19%)	31	(16%)	0.424
	T1-3	622	462	(81%)	160	(84%)	
N stage[b]	N1-2	284	215	(38%)	69	(36%)	0.681
	N0	476	354	(62%)	122	(64%)	
pStage[b]	II, III	557	404	(71%)	153	(80%)	0.013
	I	203	165	(29%)	38	(20%)	
Lymphatic invasion	Presence	483	348	(61%)	135	(71%)	0.018
	Absence	277	221	(39%)	56	(29%)	
Venous invasion	Presence	420	309	(54%)	111	(58%)	0.359
	Absence	340	260	(46%)	80	(42%)	
Surgical procedure	Ileocecal resection	93	60	(11%)	33	(17%)	0.005
	Right hemicolectomy	128	87	(15%)	41	(21%)	
	Transverse colectomy	46	33	(6%)	13	(7%)	
	Left hemicolectomy	43	32	(6%)	11	(6%)	
	Sigmoidectomy	184	146	(26%)	38	(20%)	
	Hartmann operation	24	14	(2%)	10	(5%)	
	Rectal resection	240	195	(34%)	45	(24%)	
Stoma	Permanent stoma	69	48	(9%)	21	(11%)	0.442
	Diverting stoma	22	18	(3%)	4	(2%)	
	Absence	669	503	(88%)	166	(87%)	
Elective or urgent surgery	Elective	747	560	(98%)	187	(98%)	0.636
	Urgent	13	9	(2%)	4	(2%)	
Surgical approach	Open	226	154	(27%)	72	(38%)	0.005
	Laparoscopic	534	415	(73%)	119	(62%)	
Operative blood loss, ml	≥ 100	236	168	(30%)	68	(36%)	0.116
	< 100	524	401	(70%)	123	(64%)	
Operative time, min	≥ 250	377	298	(52%)	79	(41%)	0.008
	< 250	383	271	(48%)	112	(59%)	
Severe postoperative complication[c]	Presence	56	42	(8%)	14	(7%)	0.981
	Absence	704	527	(92%)	177	(93%)	
Postoperative hospital stay, days			16.2	± 12.2	18.6	± 18.3	0.041
Adjuvant chemotherapy	Presence	230	207	(36%)	23	(12%)	< 0.001
	Absence	530	362	(64%)	168	(88%)	

a: According to the Japanese classification of colorectal carcinoma, 8th edition

b: According to the 7th edition of the UICC/TNM staging system

c: Grade 3 or higher according to the Clavien–Dindo classification

d: *P* values are from the chi-square test or Student's t-test

tub tubular adenocarcinoma, *pap* papillary adenocarcinoma, *por* poorly differentiated adenocarcinoma, *sig* signet-ring cell carcinoma, *muc* mucinous adenocarcinoma, *ASA-PS* American Society of Anesthesiologists Physical Status, *BMI* body mass index
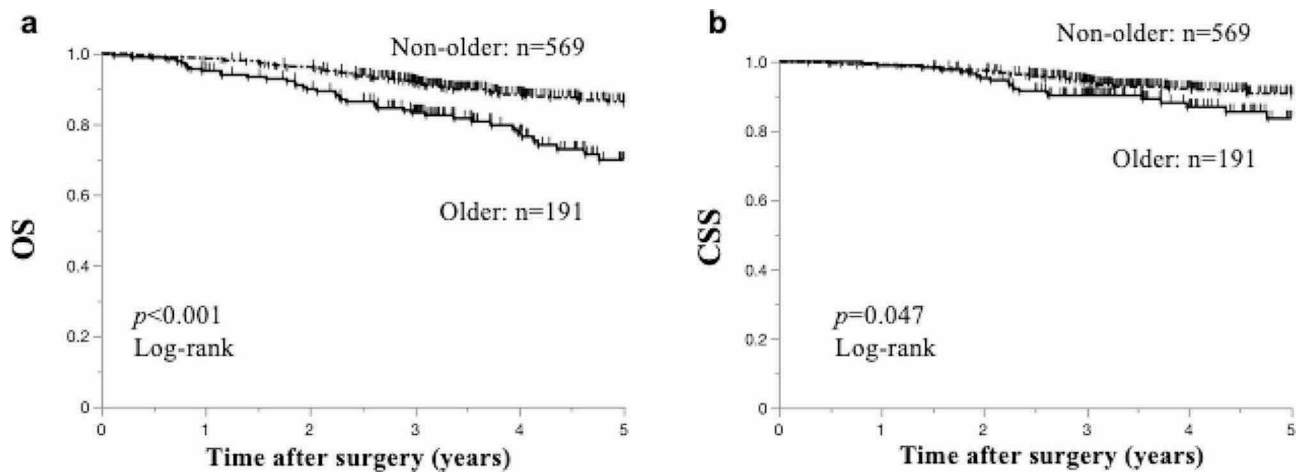
Fig. 1 Association between prognosis and age in patients with CRC. Survival analysis according to age. Overall survival (**a**) and cancer-specific survival (**b**) using the Kaplan–Meier method are shown for non-older and older patients. CRC, colorectal cancer

Table 3 Univariate and multivariate analyses for cancer-specific survival

Variables		n = 760	Univariate		Multivariate		
			5-years CSS (%)	P-value [d]	HR	95% CI	P-value [e]
Age, years	≥ 80	191	82.5	0.047	1.65	0.95–2.87	0.070
	< 80	569	90.3				
Sex	Female	331	90.3	0.610			
	Male	429	87.9				
BMI, kg/m²	> 22	389	90.0	0.444			
	≤ 22	371	87.6				
ASA-PS	≥ 3	153	75.6	< 0.001	2.47	1.45–4.20	< 0.001
	< 3	607	91.4				
Location	Rectum	251	85.1	0.025	2.10	1.26–3.50	0.004
	Colon	509	90.8				
Histopathological type[a]	por/sig/muc	62	79.4	0.019	1.65	0.82–3.33	0.156
	tub/pap	698	89.7				
T stage[b]	T4	138	74.5	< 0.001	3.19	1.83–5.55	< 0.001
	T1-3	622	92.0				
N stage[b]	N1-2	284	79.5	< 0.001	2.99	1.67–5.35	< 0.001
	N0	476	94.6				
Lymphatic invasion	Presence	483	85.7	0.001	1.40	0.70–2.79	0.331
	Absence	277	94.2				
Venous invasion	Presence	420	86.2	0.049	1.15	0.64–2.06	0.630
	Absence	340	92.0				
Severe postoperative complication[c]	Presence	56	82.3	0.069			
	Absence	704	89.4				

a: According to the Japanese classification of colorectal carcinoma, 8th edition

b: According to the 7th edition of the UICC/TNM staging system

c: Grade 3 or higher according to the Clavien–Dindo classification

d: *P* values are from the log-rank test

e: *P* values are from Cox's proportional hazard model

CSS Cancer-specific survival, *HR* Hazard ratio, *CI* Confidence interval, *tub* tubular adenocarcinoma, *pap* papillary adenocarcinoma, *por* poorly differentiated adenocarcinoma, *sig* signet-ring cell carcinoma, *muc* mucinous adenocarcinoma, *ASA-PS* American Society of Anesthesiologists Physical Status, *BMI* body mass index

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Non-older patients
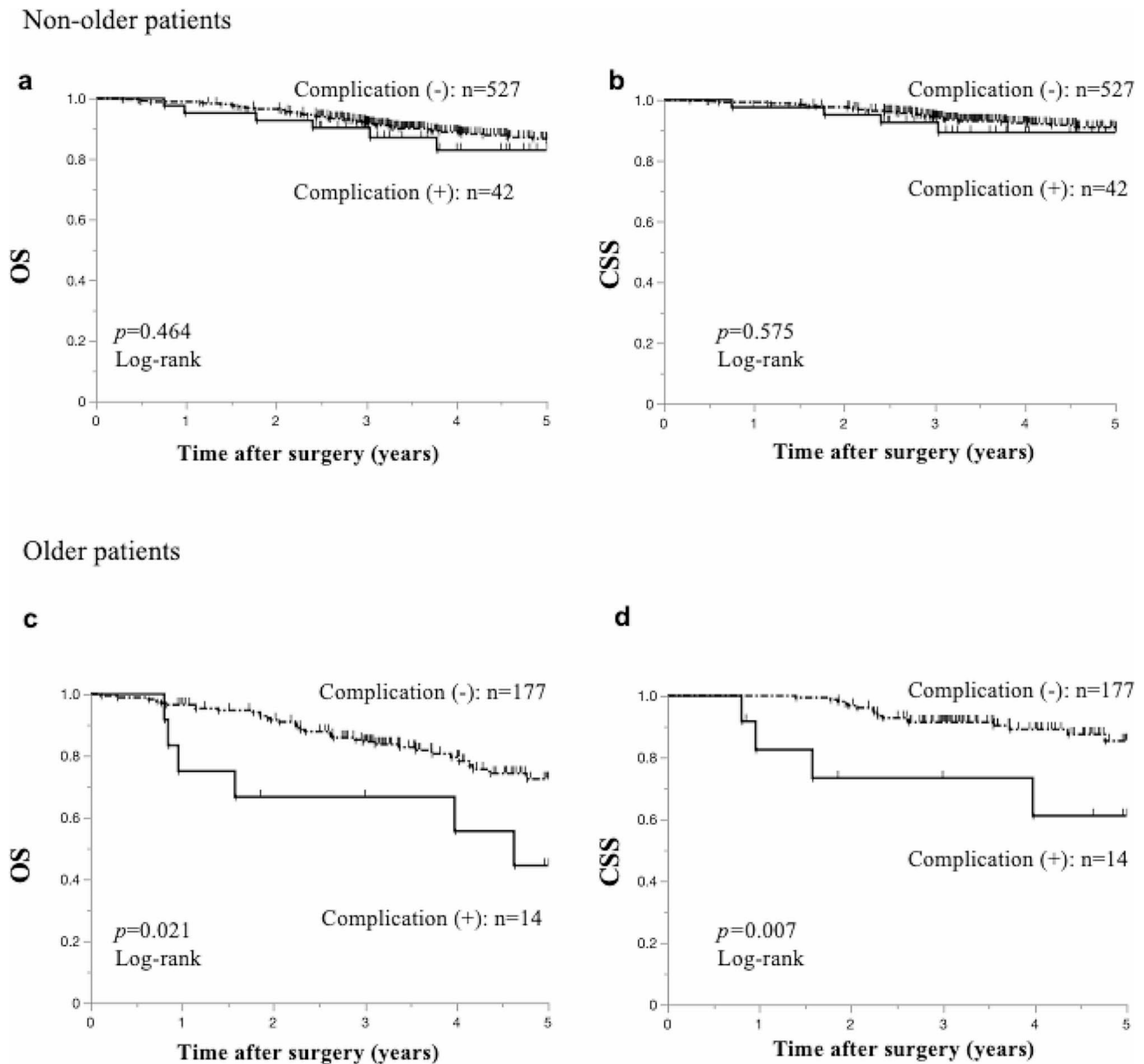

Older patients

Fig. 2 Association between prognosis and severe postoperative complication stratified based on age. **(a)** and **(b)** Survival analysis according to the severe postoperative complications that developed in non-older patients. Overall survival **(a)** and cancer-specific survival **(b)** using the Kaplan–Meier method are shown for non-older patients with or without severe postoperative complications. **(c)** and **(d)** Survival analysis according to the severe postoperative complications that developed in older patients. Overall survival **(c)** and cancer-specific survival **(d)** using the Kaplan–Meier method are shown for older patients with or without severe postoperative complications

independent prognostic factors for CSS. Older age (≥ 85 years) was not associated with poor prognosis in this analysis.

Propensity score matching analysis

To eliminate confounding factors for the occurrence of severe postoperative complications and prognosis, we performed both multivariate analysis and propensity score matching analysis. Additional file 3 shows clinicopathological factors after matching. The non-older and older groups were well-balanced with respect to covariates, except for age. In the matched cohort, the frequency of severe postoperative complication ($p=0.533$, Additional file 3), OS ($p=0.063$, Additional file 4a), and CSS ($p=0.384$, Additional file 4b) did not significantly differ between non-older and older patients. Moreover, in the older group, OS ($p=0.039$, Additional file 5c) and CSS ($p=0.033$, Additional file 5d) were significantly worse in patients with complications than in those without complications, whereas the complications were not associated

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Table 4 Univariate and multivariate analyses for cancer-specific survival in older patients

Variables		$n=191$	Univariate		Multivariate		
			5-years CSS (%)	P-value [d]	HR	95% CI	P-value [e]
Age, years	≥85	61	82.2	0.638			
	<85	130	84.0				
Sex	Female	97	79.2	0.115			
	Male	94	87.9				
BMI, kg/m^2	>22	87	87.4	0.318			
	≤22	104	80.1				
ASA-PS	≥3	61	69.6	0.156			
	<3	130	88.3				
Location	Colon	136	83.7	0.939			
	Rectum	55	83.8				
Histopathological type[a]	por/sig/muc	22	73.6	0.220			
	tub/pap	169	84.8				
T stage[b]	T4	31	57.2	<0.001	4.12	1.73–9.83	0.001
	T1-3	160	88.8				
N stage[b]	N1-2	69	73.7	0.002	3.25	1.25–8.40	0.014
	N0	122	89.5				
Lymphatic invasion	Presence	135	81.5	0.331			
	Absence	56	87.7				
Venous invasion	Presence	111	78.8	0.299			
	Absence	80	89.4				
Severe postoperative complication[c]	Presence	14	61.1	0.007	4.00	1.27–12.6	0.017
	Absence	177	85.3				

a: According to the Japanese classification of colorectal carcinoma, 8th edition

b: According to the 7th edition of the UICC/TNM staging system

c: Grade 3 or higher according to the Clavien–Dindo classification

d: *P* values are from the log-rank test

e: *P* values are from Cox's proportional hazard model

CSS Cancer-specific survival, *HR* Hazard ratio, *CI* Confidence interval, *tub* tubular adenocarcinoma, *pap* papillary adenocarcinoma, *por* poorly differentiated adenocarcinoma, *sig* signet-ring cell carcinoma, *muc* mucinous adenocarcinoma, *ASA-PS* American Society of Anesthesiologists Physical Status, *BMI* body mass index

with prognosis in the non-older group (Additional file 5a and b).

Discussion

Recent studies have demonstrated that laparoscopic resection of CRC in older patients is safe and feasible and can lead to favorable short- and long-term outcomes [5, 6, 15]. This study revealed that the incidence of severe postoperative complications did not differ between older and non-older patients with CRC. Although the prognosis of older patients was significantly worse than that of non-older patients, older age was not an independent prognostic factor for CSS.

Previous studies revealed that the occurrence of postoperative complications could be a prognostic factor for various malignancies, including CRC [7–9, 16, 17]. However, only a few studies have investigated the impact of complications on the prognosis of older patients compared with that of non-older patients. This study revealed that older patients with severe complications had significantly worse CSS and OS than those without complications; meanwhile, the occurrence of complications was not associated with prognosis in non-older patients. The multivariate analysis revealed that severe postoperative

complications were independent risk factors for CSS in older patients with CRC.

Although this study demonstrated that older patients with postoperative complications showed poor prognosis, postoperative complications may have a negative physiological effect and shorten life expectancy [18]. Therefore, various factors may affect the prognosis of older patients. To exclude the influence of these factors, patients who experienced surgery-related mortality were excluded from this study, and the prognostic significance of severe complications was evaluated based on the CSS and cumulative recurrence rates. Moreover, the frequency of adjuvant chemotherapy was lower in older patients. Elderly patients sometimes choose not to receive adjuvant chemotherapy due to the higher risk of comorbidity, poor performance status, or insufficient social support [19, 20]. These factors may have contributed to the lower frequency of adjuvant chemotherapy in the present study. In our study, the use of adjuvant chemotherapy was not a prognostic predictor in older patients, and the frequency of adjuvant chemotherapy in older patients did not differ between patients with severe postoperative complications and those without severe postoperative complications (data not shown). Despite

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efforts to control for these factors, this study was not a prospective randomized trial, and these confounders were not completely eliminated.

It remains unclear why severe postoperative complications more strongly affect the prognosis of older patients than those of non-older patients. Postoperative complications induce systemic inflammation, which can cause host immunosuppression [21, 22]. Moreover, an excessive postoperative inflammatory response can promote cell growth or enhance the migratory or invasive abilities of residual cancer cells [23, 24]. These factors may contribute to immune escape by residual cancer cells and the occurrence of micrometastases, leading to postoperative recurrence. In contrast, previous studies demonstrated that older patients might experience enhanced postoperative inflammation and impaired immunonutritional status [25–29]. Consequently, the possible mechanisms of severe postoperative complications could strongly affect the prognosis of older patients.

In aging societies, the life expectancy of older individuals has relatively increased. For example, the life expectancies of 80-year-old women and men are 12.12 and 9.22 years, respectively, in Japan [30]. Therefore, radical surgery for CRC to achieve long-term survival is necessary not only for non-older patients but also for older patients. This study suggests that the oncological outcomes in older patients are improved by preventing the occurrence of severe postoperative complications. Previous studies have demonstrated that laparoscopic surgery is more beneficial in older patients with CRC than in younger patients [15, 31]. These findings suggest that minimally invasive surgeries, such as laparoscopic or robotic surgery, contribute to the improvement in the prognosis of older patients with CRC.

This study had certain limitations. First, considering the retrospective nature of this study, patients had CRC in various locations or stages. Therefore, several possible factors may affect the prognosis of patients with CRC. However, subgroup analysis based on the tumor location or surgical approach showed that these factors did not affect the association between age and postoperative complications. Moreover, for rectal cancer, neoadjuvant or postoperative adjuvant treatment were not associated with prognosis or the incidence of postoperative complication (data not shown). Second, a selection bias existed regarding the indications of the operative method, such as laparoscopic surgery, which changed during the recruitment period of this study. The proportion of patients who underwent laparoscopic surgery was higher in the late period than in the early period. Despite this difference, the study period was not associated with severe complications or prognosis (data not shown). Third, the sample size was relatively small to investigate its prognostic impact, especially in older patients with severe postoperative complications. Despite efforts to control for confounders using multivariate analysis and propensity score matching analysis, this was not a prospective randomized trial, and these confounders were not completely eliminated in this study. Therefore, further multicenter studies with large numbers of patients are needed to confirm our results.

Conclusion

Colorectomy for CRC can be performed safely in both older and non-older patients. Severe postoperative complications may significantly affect the prognosis of older patients with CRC. Therefore, surgeons should manage various aspects of perioperative care to prevent the occurrence of severe postoperative complications and to prolong the life expectancy, even in older patients with CRC.

Abbreviations

ASA	American Society of Anesthesiologists
CI	Confidence interval
CRC	Colorectal cancer
CSS	Cancer-specific survival
HR	Hazard ratio
JSCCR	Japanese Society for Cancer of the Colon and Rectum
OS	Overall survival

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12876-024-03213-y.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Supplementary Material 5

Declarations

Ethical approval and consent to participate
This study was conducted in accordance with the ethical standards of the Japanese Red Cross Kyoto Daiichi Hospital and Japanese Red Cross Maizuru Hospital and the Declaration of Helsinki. Informed consent was obtained from all patients. The study protocol was approved by the Ethical Review Board of the Japanese Red Cross Kyoto Daiichi Hospital (No. 1424) and Japanese Red Cross Maizuru Hospital (No. 2023-01).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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