Risk Management and Healthcare Policy

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ORIGINAL RESEARCH

Association of Preoperative Frailty in Older Taiwanese Patients with Colorectal Cancer

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Purpose: Colorectal cancer (CRC) affects older adults disproportionately and presents considerable challenges to surgical management owing to age-related physiological vulnerabilities. Frailty, characterized by a reduced physiological reserve, is a recognized predictor of adverse postoperative outcomes. However, data on the impact of preoperative frailty in Taiwanese older adults with CRC are limited.

Patients and Methods: A retrospective cohort study was conducted using prospectively collected data from a Taiwanese medical center between 2016 and 2018. A comprehensive geriatric assessment (CGA) encompassing eight domains was performed to preoperatively assess patients aged ≥65 years undergoing curative CRC surgery for frailty. Patients were classified as fit (≤1 deficit) or frail (>1 deficit). Postoperative complications and overall survival (OS) were compared between the groups.

Results: Among 179 patients (median age, 74, range 65–99), 46.9% were identified as frail. Malnutrition was the most common deficiency (47%). Frail patients had significantly higher rates of intensive care unit admission (13.1% vs 3.2%, p = 0.023), major postoperative complications (50% vs 26.3%, p = 0.001), and longer hospital stay (median 11 vs 9 days, p = 0.002). All three in-hospital deaths occurred in frail patients. Frailty independently predicted worse OS (adjusted hazard ratio 1.88, 95% confidence interval 1.02–3.73, p = 0.040), with a dose-dependent increase in complication risk corresponding to the number of frailty deficits.

Conclusion: Our findings revealed that preoperative frailty is prevalent and independently associated with poor surgical and survival outcomes in older Taiwanese patients with colorectal cancer. Incorporating a CGA-based frailty assessment into preoperative planning may enhance risk stratification and guide tailored perioperative care in this vulnerable population.

Keywords: colorectal cancer, geriatric assessment, postoperative events, survival outcome

Introduction

Colorectal cancer (CRC) is a major global health concern, accounting for an estimated 1.9 million new cases and 935,000 deaths worldwide in 2020, making it the third most commonly diagnosed cancer and the second leading cause of cancer-related deaths.[1,2] In Taiwan, CRC also ranks as the third most prevalent and lethal cancer as of 2022.[3] The disease predominantly affects older adults, with a global median age at diagnosis of 68 years and approximately 60% of cases occurring in individuals aged 65 years and older, both globally and in Taiwan.[4] Population aging poses increasing challenges in managing CRC among older adults, particularly in terms of personalized surgical planning and risk stratification. In 2022, over 20% of Taiwan's population was aged 65 or older, placing Taiwan among the fastest-aging societies in Asia.[3,4] This demographic shift has led to a rising proportion of older adults requiring curative surgery for colorectal cancer, thereby highlighting the urgent need to optimize perioperative strategies and improve outcomes for this vulnerable group.

Healthy aging is a multidimensional process encompassing not only physical health but also psychological well-being, quality of life, and social participation.[5–7] Aging involves a complex interplay of physical, psychological, and

Received: 30 April 2025
Accepted: 16 August 2025
Published: 25 August 2025

social changes, and regular physical exercise, including strength training, has emerged as a key nonpharmacological strategy to promote quality of life and prevent frailty and falls among older adults.[8,9] The World Health Organization emphasizes active aging as optimizing opportunities for health, participation, and security to improve quality of life as people age.[5]

Surgical resection is the primary curative treatment for CRC. However, older patients have an increased risk of postoperative complications and mortality. Increasing age has been independently associated with higher complication and mortality rates following colon cancer surgery.[10–12] Conversely, short-term and long-term survival was reasonably good in selected octogenarians,[13,14] emphasizing the importance of nuanced preoperative assessments beyond age alone.[15]

Frailty, defined as a state of decreased physiological reserve and increased vulnerability to stressors, is a critical factor influencing surgical outcomes in older adults.[16] It is associated with a higher risk of adverse outcomes, including longer hospital stays, complications, and mortality due to cancer surgery.[16–20] Several previous studies have used different tools for frailty assessment; for example, Stępień et al[17] and Richards et al[18] utilized the modified frailty index or phenotype-based criteria, whereas Hung et al[19] specifically applied a comprehensive geriatric assessment (CGA) method. The prevalence of frailty among patients undergoing CRC surgery ranges widely from 16% to 50%, with pooled estimates of approximately 31%.[21] In the Taiwanese population, this prevalence may be even higher, with one study reporting frailty in up to 54% of older patients with intra-abdominal cancers.[22]

Although numerous studies from Western countries have established the predictive value of frailty for CRC surgical outcomes,[20,23] large-scale evidence from Taiwan remains limited. It is important to note that findings from Western studies may not be directly applicable to the Taiwanese population due to substantial differences in genetics, socio-cultural norms, and healthcare delivery. Ethnic and genetic backgrounds can influence the biological basis of frailty and postoperative recovery. Moreover, sociocultural factors, such as the strength of family support systems, dietary patterns, and societal expectations of aging, may shape how frailty manifests and is managed among older adults in Taiwan. The structure of Taiwan's healthcare system, characterized by universal coverage and relatively low patient cost-sharing, further distinguishes the context in which frailty is assessed and addressed. Considering the growing burden of CRC in older adults and the importance of personalized treatment planning, we aimed to evaluate the association between preoperative frailty and postoperative outcomes in older Taiwanese patients with CRC.

We hypothesize that preoperative frailty, as measured by CGA, is independently associated with a higher risk of postoperative complications and lower overall survival in older Taiwanese adults with colorectal cancer. Therefore, the main objective of this study was to evaluate the association between preoperative frailty and both surgical and survival outcomes in this population.

Material and Methods

Patient Selection

This retrospective study was based on prospective data collected from a medical center in Taiwan between 2016 and 2018. Eligible patients were aged 65 years or older, with newly diagnosed, histologically confirmed primary CRC, and scheduled for curative surgery. Patients with recurrent tumors, synchronous colorectal cancers, or metastatic disease at presentation were excluded. Patients were excluded if they received preoperative induction chemotherapy or radiotherapy, were scheduled for palliative or emergency surgery, or declined to provide informed consent. The exclusion of patients receiving neoadjuvant therapy ensured a homogeneous cohort of treatment-naive patients, allowing for unbiased evaluation of preoperative frailty and its association with surgical and survival outcomes. This approach enhances comparability and clinical relevance to standard surgical populations. The study protocol was approved by the Institutional Review Boards of all the participating centers.

Data Collection

Patient data were validated by retrospective medical chart review by the clinical research team. The demographic data collected included age, sex, educational level, employment status, smoking and drinking history, marital status, primary

caregiver, and Eastern Cooperative Oncology Group (ECOG) performance status. Tumor characteristics were also recorded, including primary tumor location (colon or rectum), American Joint Committee on Cancer (AJCC) staging, and tumor differentiation grade. AJCC tumor stage was pathologically determined, based on surgical and histopathological reports reviewed by the multidisciplinary oncology team. Surgical outcomes were retrospectively collected from the medical charts, including the surgical method, operative time, operative bleeding amount, R0 or R1 resection, and whether adjuvant chemotherapy was administered.

Frailty Assessment

Frailty was assessed by a trained clinical assistant using a comprehensive geriatric assessment (CGA) performed within seven days before surgery. All clinical assistants received standardized training in CGA administration, with periodic supervision by senior geriatric oncology staff to ensure inter-rater consistency and reduce assessment bias. The CGA tool and cutoff thresholds used in this study have been previously validated in Asian geriatric oncology populations, demonstrating strong predictive value for surgical and survival outcomes.[22] The CGA covered eight domains: functional status, comorbidity, polypharmacy, history of falls, mood, cognition, social support, and nutrition.[22] Patients were categorized as "fit" if they had impairment in ≤ 1 domain, and "frail" if they had impairment in >1 domain. We followed the published >1 deficit threshold, in line with established Asian validation studies.[22] Assessment tools and cutoff values for each domain are provided in Table 1. In this study, surgeons were blinded to the frailty assessment results to avoid influencing the patients' treatment decisions. The study protocol was not registered in a public database but is available from the corresponding author upon reasonable request.

Outcome Measures

The primary outcome measures were postoperative events, including major surgical complications (Accordion severity grade 2 or higher),[24] postoperative intensive care unit (ICU) stay, in-hospital death, and length of hospital stay, analyzed according to frailty status. The threshold of Accordion severity 2 or higher is widely used in surgical outcomes research to capture clinically significant complications requiring active medical intervention.[25]

The decision regarding the postoperative ICU stay was made by the surgeon based on the patient's intraoperative or postoperative condition. Additionally, the study examined overall survival between groups with and without pretreatment frailty using both univariate and multivariate analyses adjusted for factors such as age, sex, marital status, education level, body mass index, ECOG performance status, and tumor site. Overall survival was calculated from the date of surgery until death or the last date the patient was known to be alive. The median follow-up time was 40 months (range 2.5–60), with <5% of patients lost to follow-up.

Statistical Analysis

Demographic and clinical characteristics are presented as numbers for categorical variables and medians with ranges for continuous variables. The clinical characteristics of the fit and frail groups were compared using the chi-square test or

Table 1 Geriatric Assessment Results (n = 179)

Frail Domain	Tool	Cutoff Point	n	%
Nutrition	MNA-SF	≤11	84	46.9
Comorbidity	CCI[#]	≥2	59	33.0
Functionality	ADL or IADL	ADL score <100 or IADL score ≤7	50	27.9
Polypharmacy	Number of daily medications	≥5	37	20.7
Cognition	MMSE	≤23	26	14.5
Mood	GDS-4	≥9	23	12.8
Social support	Living alone	Yes	16	8.9
Falls	Number of falls within the recent 6 months	≥1	9	5.0

Abbreviations: ADL, activities of daily living; IADL, instrumental activities of daily living; MNA-SF, Mini Nutritional Assessment Short Form; CCI, Charlson Comorbidity Index; GDS-4, Geriatric Depression Scale 4-item; MMSE, Mini-Mental State Examination.

Fisher's exact test when any value was less than 5. Differences in postoperative events between subgroups were assessed using the Mann–Whitney U or chi-square test. A binary logistic regression model was used to estimate the odds ratios (ORs) and 95% confidence intervals (CIs) for variables associated with any major postoperative complications.

Univariate Cox regression analysis was performed to estimate hazard ratios (HRs) and 95% CIs for variables associated with overall survival. The proportional hazards assumption was verified using Schoenfeld residual plots. Multicollinearity among covariates was assessed using variance inflation factors (VIF), with VIF < 2 considered acceptable No correction for multiple comparisons was applied due to the exploratory nature of the analysis. Adjusted HRs in the multivariate analysis were calculated by accounting for age, sex, marital status, education level, body mass index, ECOG performance status, and tumor site. All statistical analyses were performed using SPSS (version 22.0; IBM Corp., Armonk, NY, USA), with a two-sided p-value <0.05 considered statistically significant.

Results

Frailty Assessment Tools and Results

Table 1 presents the assessment tools and cutoff points for each CGA domain. The most prevalent frailty domain was malnutrition, affecting 46.9% of the patients. This was followed by comorbidity (33.0%), functional impairment (27.9%), polypharmacy (20.7%), cognitive impairment (14.5%), mood disturbances (12.8%), lack of family support (8.9%), and history of falls within the past six months (5.0%). In total, 95 patients (53.1%) were considered "fit" with impairment in ≤ 1 domain, whereas 84 patients (46.9%) were categorized as "frail" with impairment in >1 domain.

Patient and Tumor Characteristics

Table 2 summarizes the baseline characteristics of 179 patients with CRC stratified into fit and frail groups. The median age of the overall cohort was 74 years, and frail patients were significantly older than non-frail patients (77 vs 72 years,

Table 2 Patient Characteristics

Variables	Category	Overall (n = 179)	Fit (n = 95)	Frail (n = 84)	p
Age, years	Median (range)	74 (65–99)	72 (65–90)	77 (65–99)	<0.001
Sex	Male	106 (59.2%)	64 (67.4%)	42 (50%)	0.018
	Female	73 (40.8%)	31 (32.6%)	42 (50%)	
BMI, kg/m^2	Median (range)	23.9 (14.1–39.7)	24.6 (16.7–32.8)	23.4 (14.1–39.7)	0.011
Marital status	Married	127 (70.9%)	76 (80%)	61 (60.7%)	0.005
	Other	52 (29.1%)	19 (20%)	33 (39.3%)	
Education	Less than high school	107 (59.8%)	47 (49.5%)	60 (71.4%)	0.001
	High school graduate	47 (26.3%)	27 (28.4%)	20 (23.8%)	
	College or higher	25 (14.0%)	21 (22.1%)	4 (4.8%)	
Current working status	Employment	35 (19.6%)	23 (24.2%)	12 (14.3%)	0.13
	Not employment	144 (80.4%)	72 (75.8%)	72 (85.7%)	
Main caregiver	Spouse	75 (41.9%)	44 (46.3%)	31 (36.9%)	0.22
	Other	104 (58.1%)	51 (53.7%)	53 (63.1%)	
Smoking	Yes	72 (40.2%)	42 (44.2%)	30 (35.7%)	0.25
Drinking	Yes	64 (35.8%)	38 (40%)	26 (31%)	0.22
ECOG performance scale	0	130 (72.6%)	82 (86.3%)	48 (57.1%)	<0.001
	1	30 (16.8%)	7 (7.3%)	23 (27.4%)	
	2	19 (10.6%)	6 (6.3%)	13 (15.5%)	

(*Continued*)

Table 2 (Continued).

Variables	Category	Overall (n = 179)	Fit (n = 95)	Frail (n = 84)	p
ASA score	2	14 (7.8%)	11 (11.6%)	3 (3.6%)	0.08
	3	164 (91.6%)	84 (88.4%)	80 (95.2%)	
	4	1 (0.6%)	0	1 (1.2%)	
Tumor site	Colon	134 (74.9%)	78 (82.1%)	56 (66.7%)	0.017
	Rectum	45 (25.1%)	17 (17.9%)	28 (33.3%)	
AJCC tumor staging	I	45 (25.1%)	28 (29.5%)	17 (20.2%)	0.40
	II	51 (28.5%)	23 (24.2%)	28 (33.3%)	
	III	58 (32.4%)	30 (31.6%)	28 (33.3%)	
	IVa	25 (14%)	14 (14.7%)	11 (13.1%)	
Tumor grade	Well	34 (19%)	18 (18.9%)	16 (19%)	0.73
	Intermediate	129 (72.1%)	70 (73.7%)	59 (70.2%)	
	Poorly	16 (8.9%)	7 (7.4%)	9 (10.7%)	

Abbreviations: BMI, body mass index; ECOG, Eastern Cooperative Oncology Group; ASA, American Society of Anesthesiologists; AJCC, American Joint Committee on Cancer; ASA, American Society of Anesthesiologists.

$p < 0.001$). Compared with frail patients, fit patients comprised a higher proportion of males (67.4% vs 50%, $p = 0.018$), had a higher median body mass index (BMI; 23.4 vs 24.6 kg/m², $p = 0.011$), were more likely to be married and have a higher level of education in terms of completing college or higher (22.1% vs 4.8%, $p = 0.001$), had an ECOG score of 0 (86.3% vs 57.1%, $p < 0.001$), and had a higher incidence of colon cancer (82.1% vs 66.7%, $p = 0.017$). Employment status, primary caregiver, smoking history, alcohol consumption, American Society of Anesthesiologists classification, tumor staging, and histological grade did not differ significantly between the two groups.

Surgical Measures and Percentage of Subsequent Adjuvant Chemotherapy

The association between frailty and surgical measures is shown in Table 3. The surgical method, median operative time, median operative bleeding volume, rate of R1 resection, and percentage of patients receiving adjuvant chemotherapy were similar between the two groups.

Postoperative Events

As shown in Table 4, postoperative events revealed that, although in-hospital mortality was low across the cohort, all three recorded deaths occurred in frail patients, suggesting a trend of increased perioperative mortality in frail individuals (3.6% vs 0%, $p = 0.10$). Furthermore, frail patients exhibited significantly worse postoperative events than fit patients, including

Table 3 Surgical Outcomes and Postoperative Adjuvant Chemotherapy

Variable	Overall (n = 179)	Fit (n = 95)	Frail (n = 84)	p
Surgical method				
Open	41 (22.9%)	19 (20.0%)	22 (26.2%)	0.33
Laparoscopy	138 (77.1%)	76 (80.0%)	62 (73.8%)	
Median operative time, minutes (range)	247 (75–536)	247 (101–510)	251 (78–536)	0.49
Median bleeding amount, mL (range)	50 (10–1800)	50 (10–1800)	50 (10–900)	0.39
R1 resection	20 (11.2%)	13 (13.7%)	7 (8.3%)	0.26
Adjuvant chemotherapy	81 (45.3%)	45 (47.4%)	36 (42.9%)	0.81

https://doi.org/10.2147/RMHP.S535855

Table 4 Postoperative Events

Events	Overall (n = 179)	Fit (n = 95)	Frail (n = 84)	p
Intensive care unit stay, n (%)	14 (7.8%)	3 (3.2%)	11 (13.1%)	0.023
Any grade II or higher complication, n (%)	67 (37.4%)	25 (26.3%)	42 (50%)	0.001
In-hospital death, n (%)	3 (1.7%)	0	3 (3.6%)	0.10
Median length of hospital stay, days (range)	9 (4–84)	9 (4–29)	11 (4–84)	0.002

Table 5 Relative Risk of Any Major Surgical Complication According to the Number of Frailty Deficits

Number of Frail Deficits	n of Events/Total n (%)	Odds Ratio (95% CI)	p
0	8/40 (20.0)	1 (reference)	
1	17/55 (30.9)	1.79 (0.68–4.69)	0.24
2	19/38 (50.0)	4.00 (1.47–10.9)	0.007
3	10/23 (43.5)	3.08 (0.99–9.54)	0.052
4	8/15 (53.3)	4.57 (1.28–16.4)	0.020
5	3/4 (75.0)	12.0 (1.10–131.2)	0.042
6	2/4 (50.0)	4.00 (0.49–32.9)	0.20

Abbreviation: CI, confidence interval.

a higher proportion of patients requiring ICU admission (13.1% vs 3.2%, p = 0.023), higher incidence of major postoperative complications (50% vs 26.3%, p = 0.001), and longer median length of hospital stay (11 days vs 9 days, p = 0.002).

Association of Frailty Domain Deficits with Major Postoperative Complications

Table 5 presents the relative risk of at least one major postoperative complication based on the number of frailty domain deficits among patients with CRC. Patients without frailty domain deficits had the lowest complication rate (20%) and served as the reference group. The risk of complications progressively increased as the number of frailty domain deficits increased. Patients with two deficits had a significantly higher risk (OR 4.00, 95% CI 1.47–10.9, p = 0.007), while those with five deficits had the highest risk (OR 12.0, 95% CI 1.10–131.2, p = 0.042).

Overall Survival

Forty patient (22.3%) deaths were recorded after a median follow-up of 40 (range 2.5–60) months. The mortality rates in the fit and frail groups were 14.7% and 31.0%, respectively. As shown in Figure 1, survival times differed significantly based on frailty status, with the 1-, 2-, and 3-year survival rates being 97.9%, 86.9%, and 85.8%, respectively, in fit patients compared with 88.1%, 78.1%, and 68.0%, respectively.

The results of the univariate and multivariate analyses for overall survival are shown in Table 6. The univariate analysis revealed that frail patients had a 2.34-fold increased risk of mortality compared with fit patients (HR 2.34, 95% CI 1.22–4.47, p = 0.011). Moreover, even after adjusting for potential confounders—including age, sex, marital status, education level, BMI, ECOG performance status, and tumor site—frailty remained an independent predictor of worse overall survival (adjusted HR 1.88, 95% CI 1.02–3.73, p = 0.040).

Discussion

Compared with studies conducted among Western populations,[20,23] the present study revealed that preoperative frailty was associated with higher postoperative complications and poorer survival outcomes in an older Taiwanese population with CRC. Frail patients experienced a considerably higher incidence of major postoperative complications, prolonged hospital stays, and an increased need for ICU admission than fit patients. Moreover, even after adjusting for potential confounders, frailty was identified as an independent predictor of poor overall survival. Our findings suggest the

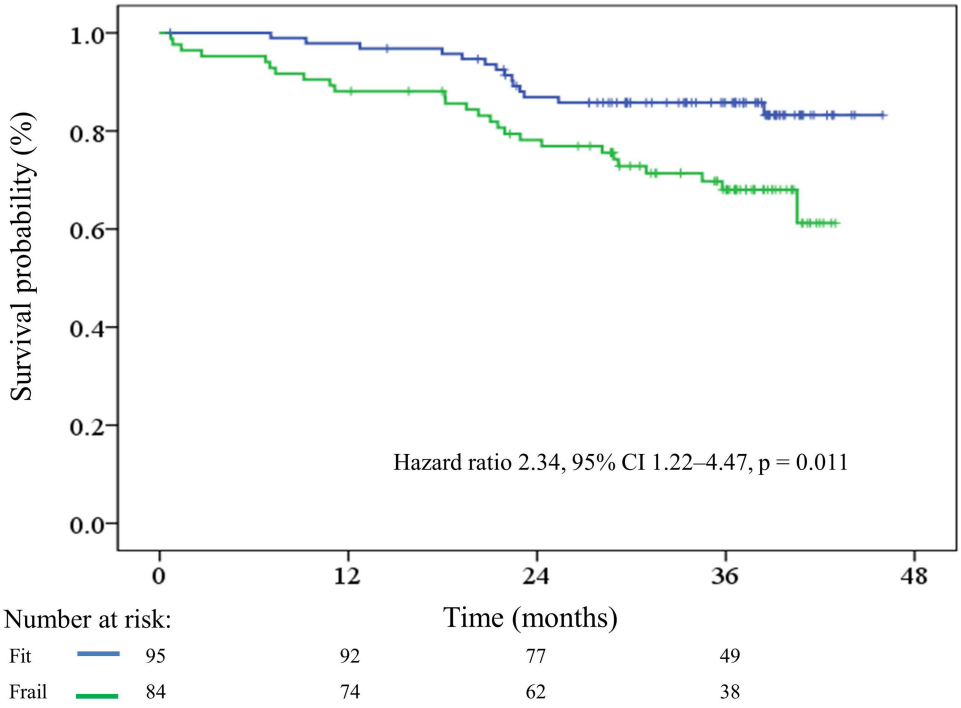

Figure 1 Overall survival according to frailty status.

importance of frailty assessment for preoperative risk stratification of older patients with CRC, given the increase in the aging population in Taiwan.

The increased postoperative complication rates in frail patients may be mediated by chronic systemic inflammation, immune dysregulation, and sarcopenia, all of which impair physiological resilience to surgical stress. These underlying biological mechanisms compromise tissue repair, impair the immune response, and limit the ability to recover from operative trauma, resulting in greater susceptibility to complications and prolonged recovery times.

A systematic review of 16 studies involving 245,747 patients reported that the pooled prevalence of frailty in older adults undergoing CRC surgery was 28.1%,[21] indicating that frailty is common among older adults with CRC. The high prevalence of frailty observed in our cohort may reflect not only assessment methodology but also underlying cultural and structural differences in the Taiwanese context. These may include limited implementation of active aging programs, traditional dietary patterns that may not optimize muscle and bone health, and restricted access to preoperative geriatric rehabilitation or preventive health services for older adults in Taiwan. We employed the CGA for frailty assessment,[22] which provides a more comprehensive evaluation than studies utilizing single-index measures, such as the Fried Frailty Phenotype[20] or the modified Frailty Index.[12,21,26] Notably, only a few studies in the literature, such as Hung et al[19] have used a CGA-based frailty assessment comparable to our methodology. Other cited works have primarily relied on alternative indices, potentially contributing to variations in frailty prevalence and clinical implications.

Table 6 Univariate and Multivariate Analyses for Overall Survival

	Univariate ANALYSIS		Multivariate Analysis	
	Hazard Ratio (95% CI)	**p**	**Adjusted Hazard Ratio[#](95% CI)**	**p**
Fit	1 (reference)		1 (reference)	
Frailty	2.34 (1.22–4.47)	0.011	1.88 (1.02–3.73)	0.040

Notes: [#]Adjusted for age, sex, marital status, education level, body mass index, ECOG performance status, and tumor site.
Abbreviation: CI, confidence interval.

https://doi.org/10.2147/RMHP.S535855

While some studies included only CRC patients with non-metastatic disease,[20] 14% of our cohort had stage IVa disease. Additionally, geographic and demographic factors, including Taiwan's aging population and potentially lower baseline health status owing to dietary and lifestyle differences, may have contributed to this variation. Importantly, our study enrolled patients who were eligible to undergo CRC surgery, with 93% of the patients having an ECOG performance score of 0 or 1. Despite the highly selected patients with excellent ECOG performance, the frailty rate remained at 46.9%, indicating that frailty was even more prevalent among older Taiwanese patients with CRC.

In the current study, we identified a clear trend revealing that the risk of major surgical complications increased correspondingly with an increase in the number of frailty deficits. Moreover, we previously reported a similar phenomenon as a linear correlation between treatment-related toxicity and increasing numbers of frailty deficits in older patients undergoing cytotoxic chemotherapy.[27] Although the small sample size for some frailty deficit categories resulted in wide CIs, the overall trend demonstrated a dose-dependent relationship between frailty burden and postoperative morbidity. These findings emphasize the importance of utilizing a comprehensive frailty assessment tool in the older population rather than only using a frailty screening tool,[28] given that patients with multiple frailty deficits are at a substantially higher risk for developing major postoperative complications.

Among the CGA domain deficits assessed, malnutrition was the most prevalent (47%), whereas a history of falls within the past six months was the least common (5%). The high prevalence of malnutrition aligns with previously reported findings, as older patients with CRC frequently experience weight loss and muscle depletion due to cancer-related metabolic changes and gastrointestinal symptoms.[29] Additionally, systemic inflammation and anorexia frequently occur in patients with malignancies, further exacerbating nutritional deficiencies.[30] In contrast, the lower prevalence of falls in our cohort may be attributed to the relatively preserved ambulatory function in patients who were eligible for surgery. Closed-knit family structures and supportive living environments for older adults in Taiwan may have diminished their need for independent mobility, potentially contributing to the lower incidence of falls among this patient population. Furthermore, the strong familial support systems prevalent in Taiwan could have led to the under-reporting of fall history by patients, given that patients may have relied more on family caregivers for daily activities.[31,32]

Our results showed that while surgical approaches, operative duration, intraoperative blood loss, and rates of adjuvant chemotherapy administration were comparable between fit and frail patients, the frail cohort experienced markedly worse postoperative outcomes. Likewise, one early study reported that intraoperative complications did not differ between patients aged <65 and ≥65 years undergoing CRC surgery, whereas notable differences in postoperative and late complications were observed in older patients.[11] This disparity in intraoperative and postoperative complications may be attributed to the inherent physiological vulnerability of frail individuals, who are more susceptible to stresses associated with surgery and exhibit impaired recovery despite receiving similar perioperative management. Frail patients may have diminished physiological reserves and reduced functional recovery capacity, rendering them more prone to complications despite undergoing similar surgical interventions.[33] Additionally, decisions regarding adjuvant chemotherapy may be primarily influenced by oncological factors rather than the frailty status alone, particularly for patients who recover sufficiently after the surgical procedure.[34] According to a recent review, interventions proven to be efficacious in clinical trials (eg, exercise, nutritional supplementation, and CGA) have not consistently shown similar effectiveness in routine care, indicating challenges in implementation.[35] Hence, to improve postoperative outcomes in frail patients, routine preoperative frailty assessments and individualized care planning are essential. Prehabilitation, combining nutrition, exercise, and psychological support, may enhance surgical resilience among frail patients. Furthermore, a multidisciplinary team approach ensures comprehensive perioperative care, whereas early mobilization and rehabilitation support postoperative recovery.[36] Finally, decisions regarding adjuvant chemotherapy should consider postsurgical functional recovery rather than oncological factors alone.[17]

The key strengths of our study include the use of prospectively collected data, a CGA-based frailty assessment, a well-defined cohort of older Taiwanese patients with CRC, and the integration of both short- and long-term clinical outcomes. This study has several limitations. The retrospective design restricts our ability to draw causal inferences. Our single-center cohort may not fully represent the diversity of the Taiwanese population, and unmeasured confounders or selection biases may remain despite adjustment for key variables. Future multicenter prospective studies would allow better generalizability and more robust adjustment for Taiwan-specific healthcare delivery and demographic factors.

Future research should explore the roles of inflammatory and hormonal biomarkers in mediating frailty and postoperative outcomes. Additionally, the effectiveness of multimodal prehabilitation programs, including nutrition, exercise, and psychological support, should be rigorously evaluated in controlled clinical trials targeting older adults with CRC.

Our findings underscore the importance of integrating frailty assessment into preoperative pathways for older CRC patients. We recommend incorporating CGA into standard preoperative clinical workflows, ideally led by a multidisciplinary team including surgeons, geriatricians, nutritionists, and physiotherapists. Such an approach can facilitate individualized surgical preparation, guide oncologic decision-making, and ultimately improve postoperative and long-term outcomes in this vulnerable population.

Conclusion

This study highlights the notable negative impact of preoperative frailty on postoperative outcomes in older Taiwanese patients with CRC. These findings underscore the urgent need for a comprehensive frailty assessment and risk stratification in the preoperative management of this vulnerable population. Integrating frailty assessments into routine clinical practice may help identify high-risk individuals and guide personalized perioperative care to optimize outcomes. Given Taiwan's rapidly aging population, it is imperative that national clinical guidelines incorporate frailty assessment as a key criterion in CRC surgical planning.

Abbreviations

CRC, colorectal cancer; ECOG, Eastern Cooperative Oncology Group (ECOG); AJCC, American Joint Committee on Cancer (AJCC), CGA, comprehensive geriatric assessment; ICU, intensive care unit; OR, odds ratio; CI, confidence interval; HR: hazard ratio; BMI, body mass index.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Informed Consent

The protocol for this research project has been approved by the suitably constituted Institutional Review Board of Chang Gung Memorial Hospital (approval no. 201600916B0) and it conforms to the provisions of the 2013 Declaration of Helsinki.

Consent to Participate

All informed consent was obtained from the subject(s).

Acknowledgments

The authors gratefully acknowledge the assistance of the patients who participated in this study.

Author Contributions

Conception and design of study: JSW, CCL, SHH, CKL, YSH, WCC; Acquisition of data: CCL, SHH, CKL; Analysis and interpretation of data: JSW, CCL, WCC; Drafting of the manuscript: JSW, CCL, SHH, CKL, YSH, WCC. All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This work was supported by research grants from the Chang Gung Memorial Hospital at Linkou, Taoyuan, Taiwan, R.O.C. (CMRPG3L1611 and CORPG3N0151); the Ministry of Health and Welfare, Taiwan, R.O.C. (MOHW114-TDU

-B-222-144011); and the National Science and Technology Council, Taiwan, R.O.C. (NSTC 111-2314-B-182A-162 and NSTC 112-2314-B-182A-152).

Disclosure

The authors report no conflicts of interest in this work.

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