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A prediction model for low functional status after colorectal cancer surgery: A retrospective cohort study using administrative data

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ABSTRACT

Introduction: Colorectal cancer (CRC) accounts for 10% of all cancer incidences globally and often affects older populations and people with poor nutrition. As such, we developed a prediction model for low functional status following CRC surgery using inpatient data collected during routine practice, and investigated the relationship between low functional status and outcomes.
Methods: Data from 690 patients who underwent CRC surgery were analysed, and the Barthel Index was used to evaluate functional status [activity of daily living (ADL)]. A low-ADL status was defined as a lower score at discharge than at admission, and unchanged complete dependence from admission to discharge. The model input data included 10 basic characteristics, eight comorbidities, and four laboratory parameters. The final model was developed using stepwise logistic regression.
Results: The low-ADL predictive model was successfully developed using nine variables: age, ADL dependence, nursing home residency, ambulance use, disturbance of consciousness on admission, diabetes, cerebrovascular disease, low creatinine, and low protein (c-statistics = 0.857). Only 6.5% of high-ADL patients were unable to return home following discharge; in contrast, 53.5% of low-ADL patients were unable to return home. Low-ADL patients also had significantly longer post-operative hospital stays and higher medical costs than high-ADL patients.
Conclusion: Low-ADL patients had decreased rates of discharge to homes, experienced longer hospital stays, and incurred higher medical costs than high-ADL patients. Pre-operative prediction of low ADL status is important, and essential for taking efficient preventive measures.

1. Introduction

Colorectal cancer (CRC) accounts for 10% of all cancer incidences globally and 9.4% of cancer-related deaths [1]. Approximately 1.93 million new CRC cases were diagnosed in 2020, with 0.94 million CRC-related deaths reported [1]. The incidence of CRC has increased significantly in developing countries owing to increases in westernised lifestyles and diets [2,3]. The total number of new CRC cases is suggested to reach 3.2 million by 2040 [1].

The average age of onset for colon cancer in men and women is 68 and 72 years, respectively, while that for rectal cancer is 63 years [4]. A large study performed in Canada reported that patients aged over 80 years accounted for 20% of all patients with CRC and these patients were 11 times more unlikely to return home following surgery than those aged under 65 years [5]. As the aging population continues to increase in both developed and developing countries, the number of older patients with CRC will continue to rise [6]. Moreover, older patients often experience decreased physical functionality even without post-operative complications [7], and in particular, patients with CRC frequently suffer from malnutrition, sarcopenia, and frailty due to gastrointestinal disorders [8,9]. Poor nutrition and frailty have been identified as independent predictors of worse functional outcomes following colorectal surgery [10,11]. Additionally, patients with sarcopenia have extended hospital stays, decreased rates of discharge back to their homes, and increased hospital costs compared with patients without sarcopenia following major abdominal surgeries [12]. In particular, the cost of

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patient care has been shown to increase in proportion to the number of functional impairments [13]. As such, post-operative functional decline increases medical costs and strains healthcare resources and is, therefore, a public health concern. Like mortality and morbidity, predicting post-operative functional decline is important for treatment selection and pre-operative preparation for patients and caregivers. However, only a limited number of studies have assessed functional decline following CRC surgery compared with studies examining mortality and morbidity [7,14].

Therefore, this study aimed to investigate whether pre-operative patient information can predict post-operative activities of daily living (ADL) scores. There are various methods to evaluate functional decline, such as measuring muscle strength and walking distance; however, we selected an ADL score as it is a suitable tool that is directly linked to the burden on caregivers and social security costs. Among similar ADL scales, the Barthel Index presents a lesser burden for patients and is a highly reliable tool [15]. It has also been used to assess functionality in patients with cancer, demonstrating accuracy and reliability [16]. We developed a prediction model for low functional status following colorectal surgery using inpatient data collected at our group hospitals, and compared the prediction model results with the calculated results from the Geriatric Nutritional Risk Index (GNRI) [17] and physiological scores of the Colorectal-Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity (CR-POSSUM) [18]. In addition, we investigated the relationship between low functional status and rates of discharge to patients' homes, length of hospital stay, and medical cost.

2. Material and methods

2.1. Data sources

This retrospective cohort study was conducted using data obtained from 81 hospitals nationwide (41 prefectures) via the Diagnosis Procedure Combination (DPC) administrative claims database, between 1 January 2016 and 31 December 2019. The DPC database is a data collection system for acute-phase inpatients, developed in Japan [19]. It is managed by the Japanese Ministry of Health, Labour, and Welfare and its validity has been established [20]. The work has been reported in line with the STROCSS criteria [21].

2.2. Patient and variable selection

The inclusion criteria were male and female patients who underwent CRC surgery during the study period. All the CRC surgeries were open operations, including segmental resection, hemicolectomy, and total colectomy. Patients were excluded if they died during hospitalisation, had incomplete ADL or laboratory data, had unclear cancer staging or hospitalisation route information.

Data extracted from the DPC database included age, sex, height, weight, main diagnosis, cancer stage, surgical procedure, treatments before surgery, information on dwelling place before admission, comorbidities, consciousness level on admission, and functional status (based on the patient's ability to perform tasks related to ADL at admission and discharge). Body mass index (BMI) was calculated using height and weight measurements. Both underweight and obesity have been reported to increase the risk of post-operative mortality and impede functional recovery [22–24]. However, most patients in this study were lean, and only 3.5% of the patients had a BMI $\geq$30 kg/m^2. Therefore, patients were divided into two BMI groups: <18.5 kg/m^2 and $\geq$18.5 kg/m^2. Because anaemia, malnutrition, sarcopenia, and renal dysfunction have been reported to affect functional prognosis, haemoglobin (Hb), total serum protein (TP), albumin (Alb), creatinine (Cre), and blood urea nitrogen (BUN) were included in the laboratory parameters [25–29]. The standard values for these tests were set based on past reports [30–32] and standard values in Japan [33]. Although unusual, lower-than-normal Cre values were treated as variables, because low Cre levels signify decreased skeletal muscle mass, which may be associated with post-operative complications and functional decline [34,35]. The functional status of ADL included the following 10 parameters: eating, transferring, grooming, toileting, bathing, walking on a flat floor, using stairs, dressing, defecating, and micturating [36]. The low-ADL group was defined as patients with a lower score at discharge than at admission and patients with an unchanged score of 0 (completely dependent) from admission to discharge. The high-ADL group was defined as patients with improved discharge scores compared with admission scores and patients with high scores (fully independent) at admission and discharge. There is a limit to functional evaluation methods, including the Barthel Index, and floor and ceiling effects are observed such that further changes cannot be measured [37]. Therefore, we decided to categorise the cases that maintained the lowest and highest scores into the low-ADL and high-ADL groups, respectively [38].

2.3. Baseline models

The GNRI is a tool developed for assessing nutritional status for older hospitalized patients and is reported to be simple and predictive of morbidity and mortality [17]. Because many patients undergoing colorectal surgery are expected to also have nutritional problems, we decided to use this assessment tool as a baseline model. The GNRI score is obtained by inputting the albumin value, body weight and ideal body weight (calculated from age and sex) in the following formula: GNRI = [1.489 × albumin (g/dL)] + [41.7 × (weight/ideal weight)].

CR-POSSUM has been reported to accurately predict post-operative mortality after colorectal surgery [18]. It consists of physiological and operative severity scores; however, only the physiological scores were used in this study. This is because this study was intended for pre-operative evaluation and the degree of surgical burden is a modifiable factor. The CR-POSSUM is calculated by summing scores assigned to the following six parameters: age, presence or absence of heart failure, systolic blood pressure, heart rate, BUN, Hb.

2.4. Prediction models

The prediction model for functional decline was developed using the following 22 input variables: (i) ten basic characteristics: age, sex, BMI, ADL dependence score at admission, dwelling place before admission, ambulance use, consciousness level at admission, oxygen inhalation before surgery, stoma, and cancer stage; (ii) eight comorbidities: hypertension, diabetes, cerebrovascular disease, dementia, liver disease, congestive heart failure, chronic pulmonary disease, and renal disease; and (iii) four pre-operative laboratory test results: Hb, TP, Cre, and BUN. Consciousness levels at admission were evaluated using the 10-grade Japan Coma Scale [39]. All alertness grades lower than the 'alert' level were considered to have impaired consciousness. Cancer stages were classified by simplifying the Japanese Society for Cancer of the Colon and Rectum staging system developed based on the TNM classification; Stages 0 and 1 are stages in which there is no lymph node metastasis or distant metastasis and the cancer has not crossed the muscularis propria, Stage 2 is cancer beyond the muscularis propria without metastasis, Stage 3 is the stage with lymph node metastasis but no distant metastasis, and Stage 4 is the stage with distant metastases [40,41]. Comorbidities were defined based on the International Statistical Classification of Diseases and Related Health Problems, 10th revision code, and the Charlson Comorbidity Index score as coded by Quan et al. [42]. A Hb threshold of < 8 g/dL was used to categorise severe anaemia in accordance with the World Health Organization guidelines [30]. Meanwhile, the thresholds for TP, Cre, and BUN, based on previous studies, were set as < 6 g/dL, < 0.46 mg/dL, and > 20 mg/dL, respectively [31,33].

Multivariable analysis was performed using a logistic regression model with ADL as the dependent variable. Twenty-two variables considered clinically associated with low-ADL status were used as independent variables. The final model was developed using forward stepwise selection for variables with an inclusion and exclusion criterion of $p < 0.2$. An odds ratio (OR) with a 95% confidence interval (CI) for each predictive factor of low-ADL was estimated. Predictive probabilities for logistic models are given by exp (1/[1+exp{-h(x)}]), where h is a linear function, and x is a covariate vector. Therefore, h(x) was used as the model in this study.

The predictive performance of the models was evaluated using the receiver operating characteristic curve and c-statistics. The c-statistic for the prediction model was compared with those for the baseline models using the bootstrap test. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were estimated for each model using the cut-off estimated with the Youden index. The c-statistic with bootstrap-based optimism correction [43] and its two-stage bootstrap confidence interval [44] were also estimated for the prediction model. We conducted the Hosmer–Lemeshow test and an estimation of the Brier score and constructed the calibration plot to evaluate the calibration of the model. We conducted decision curve analysis [45] to evaluate clinical benefit of the models.

2.5. Other statistical methods

No power analysis was performed prior to the research because all available data in the existing Database was used. Statistical analyses were performed using SPSS software version 26 (IBM, Armonk, New York, USA), R version 4.2.3 (R Core Team, Vienna, Austria), and several packages [46,47]. Patient characteristics were analysed using univariate logistic regression analyses. The *t*-test (continuous variables) and chi-squared test (categorical variables) were used to compare outcomes between low- and high-ADL patients. A p-value < 0.05 was considered significant.

3. Results

Data from 690 patients, out of an initial 4,106, were analysed. (Fig. 1). Demographic data are shown in Table 1. The mean age was 73 ± 11 years, and 220 patients (31.9%) were aged ≥ 80 years. The mean BMI was 21.9 ± 3.9, and 20% of the patients were underweight (<18.5 kg/m^2), whereas 3.5% were obese (≥30 kg/m^2). Approximately 74% of the patients were independent in terms of pre-operative daily living activities, whereas 26% had some degree of dependence. The independent living activities most commonly affected were related to leg strength, such as climbing stairs and walking. Ninety-seven percent of patients were admitted from home, and 3% were admitted from institutions such as nursing homes. In this study, the percentages of patients with cancer stages 0 & 1, 2, 3 and 4 were 9, 29, 36 and 26%, respectively. The surgical procedures used in the 690 cases were as follows: segmental resection of the colon (14 cases), hemicolectomy (9 cases), and total colectomy (667 cases). Most patients underwent extensive colon resection surgery, and 14 patients underwent colonic and rectal surgery. Approximately 67% of patients had at least one comorbidity. Comorbidities are listed below in order of frequency: hypertension (26.2%), diabetes (19.4%), cerebrovascular disease (5.7%), dementia (5.7%), liver dysfunction (5.2%), congestive heart failure (4.9%), chronic lung disease (4.2%), and renal dysfunction (1.6%). The most common comorbidities were hypertension and diabetes. The percentage of patients with abnormal Hb, TP, Alb, BUN, and Cre results was 6.8, 26.5, 28.4, 9.4, and 8.6%, respectively.

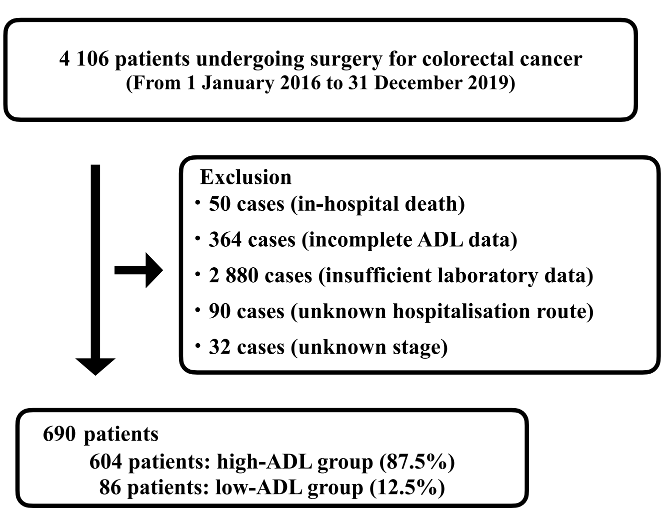

Fig. 1. Flow diagram depicting the inclusion and exclusion criteria for the analysis of post-operative activities of daily living
ADL: activity of daily living.

Table 1
Demographic data.

N		690
Age		73 ± 11
Sex	Male/Female	343/347
BMI (kg/m^2)		21.9 ± 3.9
	<18.5	138 (20.0%)
ADL_Dependence	+	180 (26.1%)
Dwelling place	Nursing Home	21 (3%)
Ambulance use	+	56 (8.1%)
Disturbance of consciousness on admission	+	27 (3.9%)
Oxygen inhalation before surgery	+	84 (12.2%)
Stoma	+	59 (8.6%)
Stage	0 and 1/2/3/4	59/202/251/178
Comorbidity disease	+	463 (67.1%)
Hypertension (ICD-10: I 10–15)	+	181 (26.2%)
Diabetes (CCI 6&12)	+	134 (19.4%)
Cerebrovascular Disease (CCI 2)	+	39 (5.7%)
Dimentia (CCI 5)	+	39 (5.7%)
Liver Disease (CCI 7 &16)	+	36 (5.2%)
Congestive Heart failure (CCI 3)	+	34 (4.9%)
Chronic pulmonary disease (CCI 10)	+	29 (4.2%)
Renal disease (CCI 14)	+	11 (1.6%)
Laboratory Data		
Haemoglobin (g/dL)		10.9 ± 2.1
Total Protein (g/dL)		6.4 ± 0.7
Albumin (g/dL)		3.3 ± 0.7
Blood urea nitrogen (mg/dL)		13.2 ± 7.0
Creatinine (mg/dL)		0.8 ± 0.6

ADL: activity of daily living, BMI: body mass index, CCI: Charlson comorbidity Index.
ICD-10: International Statistical Classification of Disease and Related Health Problems, 10th.

Of the 690 patients, 86 (12.5%) and 604 (87.5%) patients were in the low- and high-ADL groups, respectively. The following 11 of 22 variables were significantly associated with low-ADL following univariable logistic regression analyses: age (OR, 1.097; 95% CI, 1.067–1.129), ADL dependency level at admission (OR, 6.799; 95% CI, 4.198–11.011), nursing home residence (OR, 21.056; 95% CI, 7.917–56.003), ambulance use (OR, 2.064; 95% CI, 1.043–4.085), disturbance of consciousness on admission (OR, 10.423; 95% CI, 4.692–23.150), pre-operative oxygen administration (OR, 2.158; 95% CI, 1.209–3.850), diabetes (OR, 1.738; 95% CI, 1.039–2.908), cerebrovascular disease (OR, 3.465; 95% CI, 1.684–7.132), dementia (OR, 5.774; 95% CI, 2.912–11.449), low TP (OR, 3.920, 95% CI, 2.463–6.238), and low Cre (OR, 3.635; 95% CI, 1.978–6.681). Following multivariable analyses, dementia and pre-operative oxygen administration were no longer significantly associated with low-ADL, and six variables, age (OR, 1.069; 95% CI, 1.036–1.102), ADL dependency level (OR, 3.276; 95% CI, 1.840–5.829), nursing home residence (OR, 10.025; 95% CI, 2.973–33.801), disturbance of consciousness on admission (OR, 3.576; 95% CI, 1.231–10.383), diabetes (OR, 2.464; 95% CI, 1.340–4.529), and low TP (OR, 2.605; 95% CI, 1.484–4.572), were significantly associated with low-ADL. The model estimation results are described only for the variables that were significant in the multivariable model (Table 2).

The linear predictor for the low-ADL model = 0.066 × age + 1.186 × ADL dependence + 2.305 × nursing home residency – 0.709 × ambulance use + 1.274 × disturbance of consciousness + 0.902 × diabetes + 0.812 × cerebrovascular disease + 0.760 × low Cre + 0.957 × low TP – 8.400.

The sensitivity and specificity of the formula are shown in Fig. 2. C-statistics for the model of the present study, GNRI, and CR-POSSUM were 0.857 (95% CI, 0.816–0.897), 0.718 (95% CI, 0.660–0.775), and 0.708 (95% CI, 0.653–0.763), respectively. The c-statistics reported in the present study is significantly higher than those of GNRI and CR-POSSUM ($p < 0.01$). Table 3 shows the results of sensitivity, specificity, PPV, and NPV for the three models. The optimism-corrected c-statistics and their confidence interval were estimated as 0.841 (97.5% CI, 0.807–0.888), which was still larger than the c-statistics of GNRI or CR-POSSUM. The results of the Hosmer–Lemeshow test was not significant ($p = 0.925$), the Brier score was estimated as 0.081, and these results and the calibration plot (Fig. 3) indicate good calibration performance. Fig. 4 shows the results of decision curve analysis. The net benefit of the prediction model was higher than those of GNRI or CR-POSSUM.

Table 4 shows the secondary outcomes wherein 53.5% of the low-ADL patients were unable to be discharged to their homes, in contrast to 6.5% of the high-ADL patients ($p < 0.01$). Only 4% of the high-ADL patients received home care after discharge, as compared to approximately 12% of the low-ADL patients ($p < 0.01$). Finally, the low-ADL patients had significantly longer post-operative hospital stays and higher medical costs than the high-ADL patients ($p < 0.01$).

4. Discussion

The results of our study demonstrated that increased age, ADL dependence at admission, nursing home residency, disturbance of consciousness on admission, diabetes, and hypoproteinaemia were significantly associated with postoperative low ADL status. A combination of variables including cerebrovascular disease, ambulance use, and low Cre was used to develop a prediction model for low ADL following CRC surgery. The prediction formula of the present study performed better than GNRI and CR-POSSUM in terms of c-statistics and other indicators. The low-ADL patients had lower home discharge rates, longer post-operative hospital stays, and higher medical costs than the high-ADL patients.

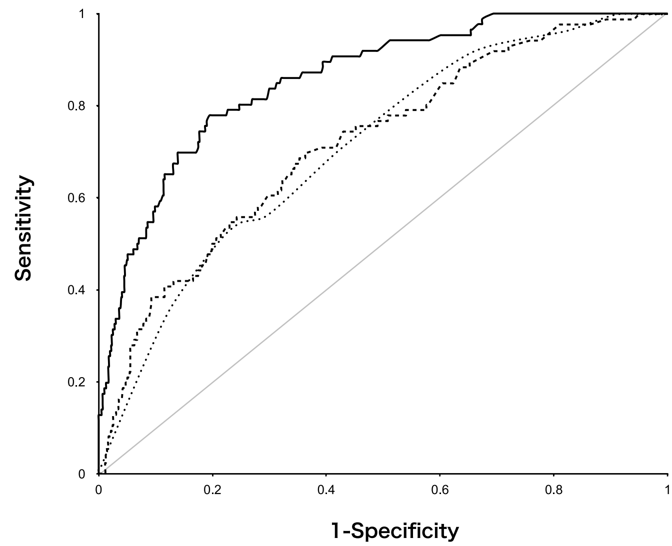

Fig. 2. Receiver operating characteristic curve for predicting low-ADL following colorectal cancer surgery
The c-statistics for the model of the present study, GNRI, and CR-POSSUM were 0.857, 0.718, and 0.708, respectively.
The solid line represents the model of the present study, the dashed line represents GNRI, and the dotted line represents the physiological score of CR-POSSUM.
ADL: activity of daily living. GNRI: Geriatric Nutritional Risk Index. CR-POSSUM: colorectal Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity.

Table 3
Comparison of the formulas.

Method	Cutoff value	Sensitivity	Specificity	PPV	NPV
Present model	0.133	77.9%	80.5%	36.2%	96.2%
GNRI	86.2	69.8%	63.7%	21.5%	93.7%
CR-POSSUM	13.5	52.3%	77.6%	25.0%	92.0%

GNRI: Geriatric Nutritional Risk Index; CR-POSSUM: Colorectal-Physiological and Operative Severity Score. PPV: positive predictive value; NPV: negative predictive value. The cutoff values were selected according to the Youden Index.

To our knowledge, only five previous studies and one review have investigated post-operative ADL following CRC surgery. However, none of those studies provided a prediction model for functional decline [7,

Table 2
Multivariable logistic regression analysis: Factor affecting low-ADL following colorectal cancer surgery.

Variables		Unadjusted analysis OR(95%CI)	p value	Adjusted analysis OR (95% CI)	p value
Age		1.097 (1.067–1.129)	<0.001*	**1.069** (1.036–1.102)	<0.001*
ADL dependence	+	6.799 (4.198–11.011)	<0.001*	**3.276** (1.840–5.829)	<0.001*
	–	1		1	
Dwelling Place	Nursing home	21.056 (7.917–56.003)	<0.001*	**10.025** (2.973–33.801)	<0.001*
	Home	1		1	
Ambulance use	+	2.064 (1.043–4.085)	0.038*	0.492 (0.186–1.304)	0.154
	–	1		1	
Disturbance of consciousness on admission	+	10.423 (4.692–23.150)	<0.001*	**3.576** (1.231–10.383)	0.019*
	–	1		1	
Diabetes	+	1.738 (1.039–2.908)	0.035*	**2.464** (1.340–4.529)	0.004*
	–	1		1	
Cerebrovascular Disease	+	3.465 (1.684–7.132)	0.001*	2.253 (0.943–5.379)	0.067
	–	1		1	
Total protein (g/dL)	<6	3.920 (2.463–6.238)	<0.001*	**2.605** (1.484–4.572)	0.001*
	6≦	1		1	
Creatinine (mg/dL)	<0.46	3.635 (1.978–6.681)	<0.001*	2.139 (0.977–4.681)	0.057
	0.46≦	1		1	

ADL: activity of daily living, CI: confidence interval, OR: odds ratio.

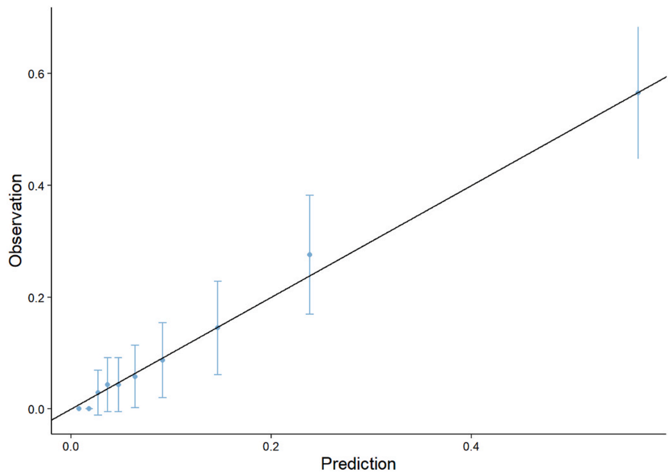

Fig. 3. Calibration plot for the prediction model.

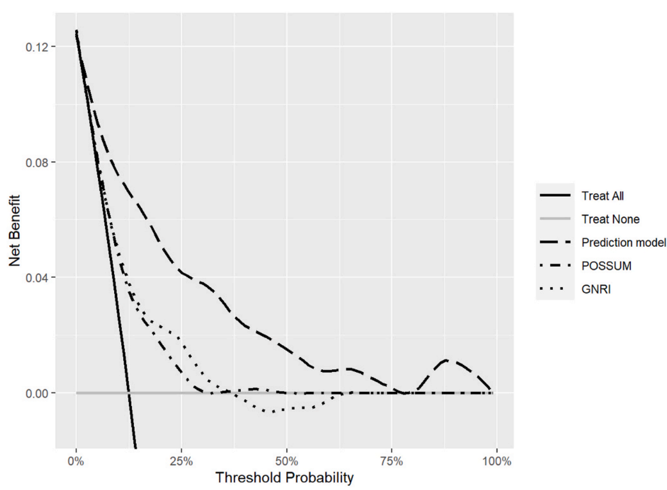

Fig. 4. Decision curve analysis
GNRI: Geriatric Nutritional Risk Index. POSSUM: colorectal Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity.

Table 4
Second outcomes of Low- and High-ADL patients after colorectal cancer surgery.

Variables	low-ADL	high-ADL	p value
N	86	604	
Discharge to Home	40 (46.5%)	565 (93.5%)	<0.001*
Discharge to Nursing Home	46 (53.5%)	39 (6.5%)	
Length of Hospital Stay after surgery (day)	27 ± 14	21 ± 15	0.001*
Medical Cost (USD)	14,422 ± 6,617	12,122 ± 5,092	0.003*

ADL: activity of daily living, 1 USD = 140 yen.

48–52]. As these previous studies investigated ADL following discharge, direct comparison with our results was difficult. Importantly, these studies reported that increased age, pre-operative ADL, dependency level, comorbidities, undernutrition, cognitive function, anaemia, and frailty affect post-operative ADL [7,48–52]. Although cognitive impairment was not included as a predictor in the present study, the average age of the included patients was 71 years, which might be too young for severe cognitive impairment. Additionally, anaemia may not have been included as a predictor variable of low-ADL in the present study because blood transfusions were actively performed in our hospitals. The extracted data lacked information regarding the precise definition of frailty. However, since low TP and Cre levels were included in the predictive model, we consider our results consistent with those of these previous studies.

In a study that investigated frailty for up to 1 month post-surgery and three studies that investigated the destination after discharge, the following were reported as factors affecting post-operative function: increased age, female sex, pre-operative ADL dependency level, weight loss, an American Society of Anesthesiologists–Physical Status (ASA-PS) score ≥ 3, laparotomy, reoperation, stoma, post-operative complications, comorbidities, malnutrition, and emergency hospitalisation [5,10,53,54]. In our study, all surgical procedures were open operations, and information regarding the ASA-PS could not be obtained; therefore, these two factors could not be examined. Despite this, excluding sex and stoma, the other variables examined in our study showed results consistent with these previous findings. Regarding the difference in the home discharge rates between the sexes, this may be affected by common gender roles, such as men not actively participating in house chores. In addition, we think stoma was not retained as an independent variable because we used ADL as the dependent variable for this study. The burden or difficulty of stoma management was not considered, and only the possibility of stoma management was evaluated in the present study. As such, the stoma may have been a contributing factor when assessed using the quality of life score.

The fact that the model in this study yielded better prediction accuracy compared with the GNRI indicates that higher pre-operative functions and independent lifestyles are as equally important as good nutrition in maintaining ADL. In addition, since CR-POSSUM is originally an index for mortality and primarily evaluates cardiac function, its inferiority in predicting post-operative ADL was within expectations. As shown in other studies [7,50,53], post-operative complications reduce post-operative ADL. However, as the purpose of the present study was to investigate whether pre-operative data could predict post-operative ADL, we did not use post-operative complications to develop our prediction model.

Despite our interesting findings, this study had a few limitations. First, most of the included patients were of a single ethnicity; therefore, it is unknown whether this model is generalizable. Second, the sample size was relatively small, especially in the low-ADL group, and need validation via large-sample studies. Third, access to laboratory test parameters was more restricted than expected, as many hospitals conducted pre-operative tests in outpatient settings before admission. In addition, laparoscopic surgery, which has recently become popular, has not yet been assessed. Finally, discharge destinations are confounded by family composition and social setting. In the future, we aim to overcome a large part of these limitations by constructing a data integration system that can obtain blood test data from all patients. Furthermore, future work is needed to investigate using machine learning models or other models with higher prediction performance.

5. Conclusions

A prediction model for low ADL following CRC surgery was successfully developed using patient information obtained during routine practice (c-statistics = 0.857). Advanced age, nursing home residency, ADL dependency level at admission, disturbance of consciousness on admission, diabetes, and hypoproteinaemia were significantly associated with low-ADL status. The low-ADL patients experienced extended hospital stays, increased medical costs, and required services such as nursing homes and home care more frequently than the high-ADL patients. Prediction of low-ADL status pre-operatively is important, and essential to take efficient preventive measures and to organise the provision of appropriate post-operative care.

Ethical approval

The study was approved by the Ethics Review Board of Kasumigaura

Medical Center Hospital (#2020-8, https://kasumigaura.hosp.go.jp).

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Author contribution

TF was involved in the study conception, design, analysis, and wrote-up. SI contributed to the interpretation of the findings. KM contributed to statistical analyses. HH supervised data collection. All authors approved the final version of the manuscript.

Registration of research studies

UMIN000049418.

(UMIN is an abbreviation for University Hospital Medical Information Network).

https://center6.umin.ac.jp/cgi-open-bin/ctr_e/ctr_view.cgi?recptno = R000056261.

Guarantor

Taeko Fukuda.

Consent

Informed consent was not required for this Cohort study.

Declaration of competing interest

The authors have no conflict of interest to declare.

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