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Original Article

External validation of a risk model for survival prediction in older patients with cancer undergoing elective abdominal surgery: a prospective cohort study

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Abstract: We previously developed a Chang Gung Memorial Hospital (CGMH) model to predict the 1-year postoperative mortality risk in patients with solid cancer undergoing cancer surgery. This study aimed to externally validate the CGMH score for survival outcome and surgical complication prediction in a prospective patient cohort. A total of 345 consecutive patients aged ≥65 years who underwent elective abdominal surgery for cancer treatment were prospectively enrolled. Patients were categorized into the low, intermediate, high, and very high-risk groups according to the CGMH score for comparison. The postoperative 1-year mortality rate was 12.5% in the entire cohort. The postoperative 1-year mortality rates were 0%, 2.2%, 14.0%, and 31.6% among patients in the low, intermediate, high, and very-high risk groups, respectively. The c-statistic of the CGMH model was 0.82 (95% confidence interval [CI], 0.76-0.88) for predicting the 1-year mortality risk. Hazard ratios for overall survival were 3.73 (95% CI, 2.11-6.57; P<0.001) and 10.1 (95% CI, 5.84-17.6; P<0.001) when comparing the high and very-high risk groups with the low/intermediate risk groups, respectively. Patients in the higher CGMH risk groups had higher risks of adverse surgical outcomes in terms of longer length of hospital stay, major surgical complications, postoperative intensive care unit stay, and in-hospital death. The CGMH model accurately predicted thesurvival probabilityand risk of adverse surgical outcomes in older patients with cancer undergoing elective abdominal surgery. Our study justifies the prospective use of the CGMH model for survival outcome and safety profile predictionfor cancer surgery in older patients.

Keywords: Cancer surgery, survival, prognostic model, surgical mortality

Introduction

Intra-abdominal cancers, including those of the colorectum, liver, stomach, and pancreas, are common and lethal malignancies, and are the 2nd, 3rd, 4th, and 7th-leading cause of cancer-related death worldwide, respectively [1]. Similar to the global trend of cancer-related deaths, these four types of malignancies are among the top ten causes of cancer-related deaths in Taiwan [2]. The median age at diagnosis for these malignancies is 67-69 years in Taiwan [2], indicating that over half the patients are older individuals at the time of diagnosis.

Radical resection is the gold standard curative treatment for intra-abdominal cancer. However, the perioperative mortality is 3-6%, 4-8%, 5-9%, and 18-25% among patients who undergo colectomy [3], gastrectomy [4], hepatic segmentectomy [5, 6], and pancreatectomy [7], respectively. The risk of perioperative mortality is more apparent in older patients undergoing cancer surgery [3, 4, 8]. The substantial portion of older patients with perioperative mortality might compromise the long-term survival benefit of curative-intent surgery; thus, a comprehensive preoperative assessment to predict surgical outcomes is crucial for the appro-

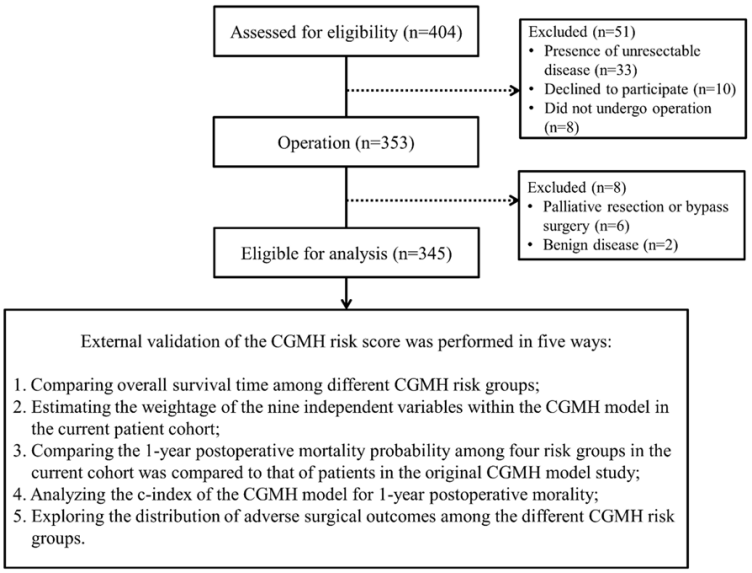

Figure 1. Study flowchart.

priate selection of older patients for cancer surgery.

In 2015, we proposed a Chang Gung Memorial Hospital (CGMH) risk model to predict 1-year postoperative mortality after cancer surgery based on a retrospective analysis of 20,632 patients with solid cancers from CGMH in Taiwan [9]. The CGMH model was constructed using nine clinical variables, including age, sex, primary tumor site, previous cancer history, tumor stage, Eastern Cooperative Oncology Group (ECOG) performance scale, admission type, comorbidity, and American Society of Anesthesiologists (ASA) score to stratify patients into four risk groups for survival discrimination [9]. The CGMH model was externally validated in 16,656 patients using cancer registry data from three medical hospitals in Taiwan [9].

The CGMH model has been demonstrated to accurately predict 1-year postoperative mortality and long-term survival outcomes [9]. However, this score has not yet been validated in a prospective study, and the association between CGMH score and surgical complications has never been explored. This study aimed to externally validate the performance of the CGMH score in predicting survival outcomes and surgical complications in a prospective patient cohort.

Methods

Patient selection

This prospective observational study was conducted between September 2016 and November 2018 at Linkou Chang Gung Memorial Hospital, the same medical center developed for the CGMH model. The inclusion criteria were as follows: age ≥65 years, pathological or radiographic diagnosis of gastric, colorectal, or hepatico-pancreatico-biliary (HPB) cancers, and curative-intent surgery for cancer treatment. Patients who had other concurrent active malignancies, and those who underwent preoperative chemotherapy and/or radiotherapy, palliative resection, or non-elective surgery were excluded from the study. In total, 345 consecutive patients were enrolled in this study. The flowchart of the study is shown in **Figure 1**.

Data collection

All included patients underwent curative-intent surgery as the primary treatment for cancer. The feasibility and methodology of the operation for each patient were determined by a tumor board discussion before surgery.

Patients' demographic and clinical data, including age, sex, marital status, educational level, smoking history, alcohol drinking history, Charlson comorbidity index (CCI), cancer type, tumor stage, Eastern Cooperative Oncology Group (ECOG) performance status, and American Society of Anesthesiology (ASA) score, were collected within one week before surgery. A modified CCI that excludes scores for patient age and cancer diagnosis was used in this study [10].

Operative information including operative method (open or laparoscopy), operative time, intraoperative blood loss, and adverse surgical outcomes (defined as any grade of postoperative complication, postoperative intensive care unit [ICU] stay, in-hospital mortality, and 30-day readmission) were collected by a well-trained

research physician using a prospectively formulated electronic data form. Surgical complications were recorded postoperatively until patient discharge, and any event with an Accordion Severity grade of ≥2 was defined as a major complication [11].

All included patients were followed up until death or December 31, 2021. Dates of death were obtained from either the Institutional Cancer Registry or National Registry of Death in Taiwan. The overall survival (OS) time was calculated from the day of surgery to the day of death or end of the study.

CGMH model

The detailed scoring for each variable in the CGMH model was described in our previous study [9]. The sum of the CGMH scores ranged from 0 to 43 points. All patients in this study were categorized into four groups based on the sum of CGMH scores according to the original study (low risk, 0-5; intermediate risk, 6-10; high risk, 11-15; and veryhigh risk, ≥15) for survival comparison.

Validation of the CGMH model

The CGMH model was validated in five ways: First, the OS among the different CGMH risk groups was compared using the Kaplan-Meier survival curve. Second, we reassessed the weightage for all nine independent variables within the CGMH model in the current patient cohort. Each variable was analyzed using univariate and multivariate Cox regression analyses to estimate its discriminative ability for overall survival. Third, the 1-year postoperative mortality probability among the four risk groups in the current cohort was compared with that of the patients in the original CGMH model (CGMH cohort). Fourth, the c-index of the CGMH model was calculated to estimate its discriminative ability in predicting 1-year postoperative mortality. Finally, we explored the distribution of adverse surgical outcomes among different CGMH groups.

Statistical analysis

Basic patient and tumor characteristics are summarized as n (%) for categorical variables and as medians with interquartile ranges (IQR) for continuous variables. Overall survival was calculated using the Kaplan-Meier method. Hazard ratios (HR) and 95% confidence intervals (CI) were estimated for each CGMH variable using Cox regression analysis. The odds ratio (OR) of 1-year postoperative mortality was calculated using a logistic regression analysis. Receiver operating characteristic (ROC) curves and the area under the curve (c-index) were used to determine the accuracy of the CGMH model in predicting the 1-year postoperative mortality rate. Statistical analysis was conducted using the IBM SPSS software,version 23.0 (IBM Corp., Armonk, N.Y., USA). All statistical assessments were two-sided, and statistical significance was set at $P<0.05$.

Results

Patient characteristics

Distribution of the patients' demographic data between the current patient cohort and the original CGMH cohort is presented in **Table 1**. In the current cohort, patients' median age was 73 years (IQR, 69-78) and 59.7% were male. The main cancer types were colorectal (59.1%), followed by HPB (24.6%), and stomach (23.5%). Most patients had disease stagesof I or II (61.4%) and ECOG performance scores of 0 (67.8%). The current cohort had more patients with disease stages of I or II; these patients were older, exclusively had gastrointestinal tract cancer with elective admission, and had a better performance status, higher ASA scores, and higher CCI scores compared to patients in the original CGMH cohort.

Table 2 summarizes each patient's CGMH score and the final risk groups according to the sum of the CGMH scores. Based on the sum of the CGMH scores, 20 (5.8%), 136 (39.4%), 113 (32.8%), and 76 (22.0%) patients were categorized into the low, intermediate, high, and very-high risk groups.

Performance of CGMH model for discriminate overall survival

After a median follow-up of 48 months (IQR, 40-53), 109 (31.6%) patients had died at the end of the study. The overall mortality rates were 0%, 12.5%, 35.4%, and 68.4% for the low, intermediate, high, and very-high risk group,

Table 1. Preoperative demographic data

Variable	Category	Current cohort, n=345	CGMH cohort, n=20,632
		n (%)	n (%)
Gender	Male	206 (59.7)	10,613 (51.4)
Age	Median, IOR	73 (69-78)	57 (48-68)
	<70	106 (30.7)	16,047 (79.5)
	≥70	239 (69.3)	4,225 (20.5)
Cancer type	Colorectum	179 (51.9)	4,766 (23.1)
	Hepatico-Pancreatico-Biliary	85 (24.6)	1,760 (8.5)
	Stomach	81 (23.5)	1,311 (6.4)
	Others	0	12,795 (62.0)
Previous cancer history	Yes	33 (9.6)	2,190 (10.6)
Tumor stage	I or II	212 (61.4)	4,193 (20.3)
	III	96 (27.8)	6,438 (31.2)
	IVa	37 (10.7)	6,023 (29.2)
	Unclassified	0	3,978 (19.3)
ECOG	0	234 (67.8)	8,646 (41.9)
	1	90 (26.1)	8,548 (41.4)
	2	19 (5.5)	2,441 (11.8)
	3	2 (0.6)	908 (4.4)
	4	0	89 (0.4)
Admission type	Elective	345 (100)	18,239 (88.4)
	Non-elective	0	2,393 (11.6)
CCI	0	103 (29.9)	14,900 (72.2)
	1	112 (32.5)	4,191 (20.3)
	2	76 (22.0)	1,056 (5.1)
	3	26 (7.5)	286 (1.4)
	4	19 (5.5)	126 (0.6)
	≥5	9 (2.6)	73 (0.4)
ASA score	1	1 (0.3)	1,418 (6.9)
	2	19 (5.5)	12,476 (60.5)
	3	324 (93.9)	6,694 (32.4)
	4 and 5	1 (0.3)	44 (0.2)
One-year postoperative mortality		43 (12.5)	1,930 (9.4)

Abbreviations: ASA, American Society of Anesthesiology; CCI, Charlson Comorbidity Index; ECOG, Eastern Cooperative Oncology Group; IQR, Interquartile Range.

respectively. The OS differed significantly among the four patient groups (pooled log-rank, P<0.001) (**Figure 2**). Because there were no death events in the low-risk group, we combined the low and intermediate-risk groups to compare the cumulative HR with those of the highand very-highrisk groups. The performance of the CGMH model in discriminating OS among patients is presented in **Table 3**. The hazard ratio was 3.73 (95% CI, 2.11-6.57; P< 0.001) and 10.1 (95% CI, 5.84-17.6; P<0.001) when comparing the high and very-high risk groups with the low/intermediate risk group, respectively.

To eliminate the effect of cancer type on the survival prediction ability of the CGMH model, all patients were further categorized as having CRC or HBP/stomach cancer for subgroup analysis (Supplementary Table 1). Of the 179 patients with CRC, the HR for OS was 3.51 (95% CI, 1.42-8.71; P=0.007) and 13.8 (95% CI, 5.81-32.8; P<0.001) when comparing the high and very-high risk groups with the low/

Table 2. Patient's CGMH model scores

Clinical variable	Category	Score	n (%)
Sex	Female	0	139 (30.2)
	Male	1	206 (32.5)
Age, years	0-69	0	106 (30.7)
	70-79	2	161 (46.7)
	≥80	4	78 (22.6)
Previous cancer history	No	0	312 (90.4)
	Yes	2	33 (9.6)
Primary tumor site	Colorectum	3	179 (51.9)
	HPB or stomach	6	166 (48.1)
Tumor stage	I or II	0	212 (61.4)
	III	5	96 (27.8)
	IV	10	37 (10.7)
ASA score	1-2	0	20 (5.8)
	3-5	1	325 (94.2)
ECOG performance	0-1	0	324 (93.9)
	2-3	1	21 (6.1)
Admission type	Elective	0	345 (100)
	Non-elective	1	0
CCI	0	0	103 (29.9)
	1-2	1	188 (54.5)
	3-4	4	45 (13.0)
	≥5	8	9 (2.6)
Risk group by sum score	Low	0-5	20 (5.8)
	Intermediate	6-10	136 (39.4)
	High	11-15	113 (32.8)
	Very-high	≥16	76 (22.0)

Abbreviations: ASA, American Society of Anesthesiology; CCI, Charlson Comorbidity Index; ECOG, Eastern Cooperative Oncology Group; HPB, Hepatico-Pancreatico-Biliary.

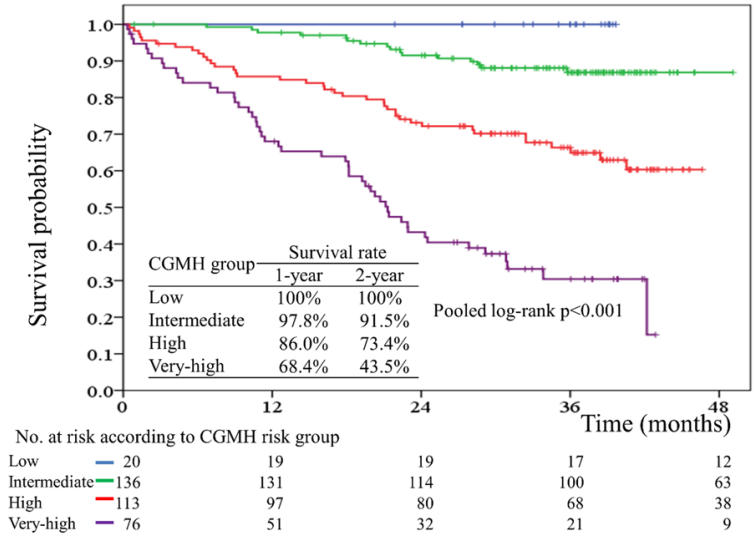

Figure 2. Survival outcomes in the CGMH risk groups.

intermediate risk groups, respectively. Of the 166 patients with HBP/stomach cancer, the HR for OS was 3.50 (95% CI, 1.69-7.26; P=0.001) and 7.21 (95% CI, 3.53-14.7; P<0.001) when comparing the high and very-high risk groups with the low/intermediate risk groups, respectively.

Univariate and multivariate analysis of each variable within CGMH model for OS

Table 3 presents the results of the univariate and multivariate analyses of each variable within the CGMH model for OS. The admission type variable was excluded from the analyses because all patients underwent elective surgery in this study. Five of the remaining eight variables, including age, tumor site, ECOG performance status, tumor stage, and CCI, were significant prognostic factors for OS in the univariate analysis. Age, tumor site, tumor stage, and CCI remained significant variables in multivariate analysis.

1-year postoperative mortality rate between current cohort and CGMH cohort

The 1-year postoperative mortality rates were 9.4% and 12.5% in the CGMH and current cohorts, respectively. The 1-year postoperative mortality rates among the low, intermediate, high, and very-high risk groups were 0%, 2.2%, 14.0%, and 31.6% in current cohort, respectively (**Figure 3**), which were comparable to those of the CGMH cohort (0.5%, 3.8%, 14.6%, and 33.8%, respectively). Patients in the high and very-high risk groups had an

Table 3. Univariate and multivariate analyses of variables in the CGMH model for overall survival

Parameters	No. of event/No. of patients (%)	Univariate analysis		Multivariate analysis	
		HR (95% CI)	*P* value	Adjusted HR (95% CI)	*P* value
Overall	109/345 (31.6)				
Sex					
female	42/139 (30.2)	1		1	
male	67/206 (32.5)	1.11 (0.75 to 1.63)	0.61	1.18 (0.77 to 1.79)	0.45
Age					
65-69	22/106 (20.8)	1		1	
70-79	51/161 (31.7)	1.64 (0.99 to 2.71)	0.052	2.69 (1.53 to 4.72)	0.001
≥80	36/78 (46.2)	2.59 (1.52 to 4.41)	<0.001	3.33 (1.86 to 5.95)	<0.001
Primary tumor site					
Colorectum	41/179 (23.9)	1		1	
HPB or stomach	68/166 (41.0)	1.29 (1.13 to 1.46)	<0.001	3.42 (2.21 to 5.28)	<0.001
Previous cancer history					
No	96/312 (30.8)	1		1	
Yes	13/33 (39.4)	1.16 (0.87 to 1.55)	0.32	1.28 (0.68 to 2.40)	0.44
Admission type					
Elective	109/345 (31.6)	--			
Non-elective	0	--			
Tumor stage					
I-II	42/212 (19.8)	1		1	
III	37/96 (38.5)	2.13 (1.37 to 3.32)	0.001	2.30 (1.45 to 3.64)	<0.001
IVa	30/37 (81.1)	7.29 (4.54 to 11.7)	<0.001	12.4 (7.10 to 21.6)	<0.001
ASA score					
1-2	3/20 (15.0)	1		1	
3-5	106/325 (32.6)	2.46 (0.78 to 7.76)	0.12	1.86 (0.57 to 6.03)	0.30
ECOG score					
0-1	95/324 (29.3)	1		1	
2-3	14/21 (33.3)	2.92 (1.66 to 5.14)	<0.001	1.51 (0.80 to 2.88)	0.21
CCI					
0	28/103 (27.2)	1		1	
1-2	54/188 (28.7)	1.05 (0.67 to 1.66)	0.83	0.95 (0.59 to 1.52)	0.83
3-4	22/45 (48.9)	2.21 (1.26 to 3.86)	0.005	1.72 (0.95 to 3.12)	0.07
≥5	5/9 (55.6)	2.82 (1.09 to 7.30)	0.033	3.12 (1.11 to 8.78)	0.031

Abbreviations: ASA, American Society of Anesthesiology; CCI, Charlson Comorbidity Index; ECOG, Eastern Cooperative Oncology Group; HPB, Hepatico-Pancreatico-Biliary; HR, Hazard Ratio.

8.41-fold (95% CI, 2.39-29.6, P=0.001) and 23.5-fold (95% CI, 6.81-81.4, P<0.001) likelihood of 1-year postoperative mortality than those in the low/intermediate risk group. The C-index of the CGMH model for predicting the 1-year mortality was 0.82 (95% CI, 0.76-0.88).

Distribution of adverse surgical outcomes among different CGMH groups

The incidences of adverse surgical outcomes in the current cohort are presented in Supplementary Table 2. Patients with a higher CGMH risk tended to have higher incidences of adverse surgical outcomes in terms of longer length of hospital stay (LOS), major surgical complications, postoperative ICU stay, and in-hospital death.

Discussion

Accurate survival prediction is crucial for patients to ascertain the benefits of anti-tumor treatment. We previously developed a CGMH

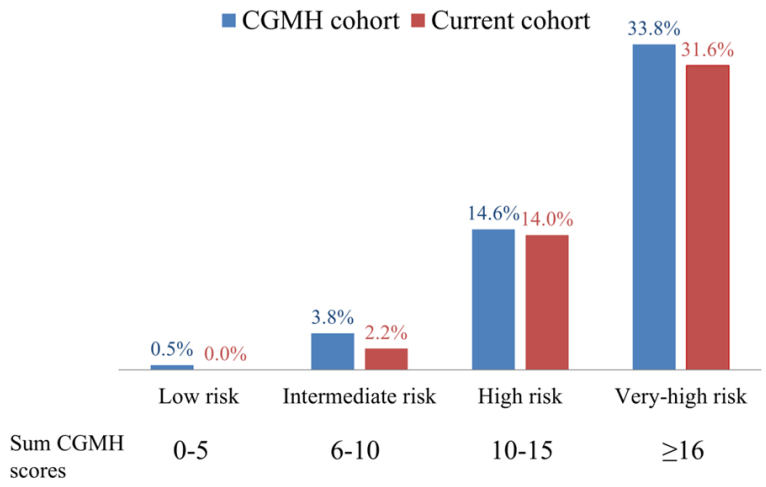

Figure 3. Postoperative 1-year mortality rate among the different CGMH prognostic groups in the CGMH (12) and current cohorts.

risk model to predict the 1-year survival probability of adult patients with solid cancers after cancer surgery [9]. This study externally validated the CGMH model for prediction of postoperative survival outcomes using a prospective cohort of older adults with gastrointestinal cancer. The results showed that the CGMH model accurately predicted 1-year mortality and long-term survival probability in older adults undergoing elective abdominal surgery for cancer. Furthermore, herein, the CGMH model could be implemented to estimate trends in the risk of adverse surgical outcomes in patients undergoing cancer surgery.

The CGMH model was derived using retrospective cancer registry data and scored using the presentation of patient characteristics (age, sex, previous cancer history, admission type, performance, ASA score, and CCI) and tumor factors (tumor site and tumor stage) to allocate patients into four risk groups for survival discrimination [9]. Despite the relatively small patient numbers due to the prospective study design and that only patients with intra-abdominal cancer were included in the current patient cohort, our results confirmed that four of the nine independent variables of the CGMH model, including age, tumor site, tumor stage, and CCI, remained independent prognosticators in predicting survival outcomes. The c-index for prediction of 1-year postoperative mortality was 0.80 in the original CGMH cohort [9]; similarly, our data showed that the CGMH model accurately predicted 1-year postoperative mortality risk with a c-index of 0.82. Because all nine clinical variables of the CGMH model are easily accessible, we believe that our data might support the generalization of the CGMH model for survival prediction in patients with cancer undergoing abdominal cancer surgery.

In terms of the prognostic and predictive values of the CGMH model for clinical use, our results showed that patients in low-risk groups should be encouraged to undergo cancer surgery because they potentially have better survival outcomes and a low incidence of surgical complications. We previously reported that radical gastrectomy is encouraged in patients aged ≥70 years with clinically resectable gastric cancer and CGMH scores of ≤20, indicating a low risk of surgical mortality [12]. The survival time was significantly better among patients who underwent gastrectomy than among those who did not (median OS, 43 vs. 16 months; P<0.001). Contrastingly, the 1-year postoperative mortality rates were 33.8% and 31.6% in the very-high risk groups of the CGMH and current cohorts, respectively. These results indicate that the treatment efficacy is limited in the very high-risk group and these patients experience adverse events from cancer surgery more frequently than those in the other groups. Given the 2-year survival rate of only 43.5%, patients in the very-high risk group should be informed that the survival benefit of cancer surgery is potentially diminished by the higher probability of postoperative complications.

One study using the SEER-Medicare database reported that the median OS was significantly longer for patients treated with pancreatectomy than for those treated with chemotherapy (15 vs. 10 months) among patients aged ≥65 years with pancreatic adenocarcinoma [13]. However, the absolute survival benefit was only 3 months when pancreatectomy was compared with chemotherapy in patients aged ≥80 years [13]. Similarly, we previously reported

comparable survival times (13.8 vs. 10.4 months, P=0.18) between surgical and non-surgical treatment in older patients with gastric cancer who had CGMH scores of >20 [12]. As a result, non-surgical treatment modalities may be considered as alternative strategies for the very high-risk patient group [13-16].

In our previous report, we hypothesized that patients with higher CGMH scores are susceptible to perioperative mortality because of the increased risk of postoperative complications [9, 12]. This study supported the hypothesis regarding patients with higher CGMH scores being associated with a higher risk of adverse surgical outcomes, including longer LOS, major surgical complications, postoperative ICU stay, and in-hospital death. Thus, the CGMH model could be implemented as a prognostic tool for predicting survival time and as a predictive tool for estimating the risk of postoperative complications after surgery in patients with cancer.

The current cohort had a higher 1-year postoperative mortality rate (12.5%) than that of the CGMH cohort (9.4%) [9]. The differences in patient demographic data between the two cohorts may partially contribute to the survival discrepancy. First, the current cohort included patients with gastrointestinal malignancies only, whereas the CGMH cohort included patients with various solid cancers. Second, the current cohort only enrolled older patients (aged ≥65 years), compared to the median age of 57 years in the CGMH cohort. In addition, patients in the current cohort had higher CCI and ASA scores than those of patients in the CGMH cohort. As older age, gastrointestinal cancer types, and higher CCI and ASA scores were negative prognosticators in the CGMH model [9], the distribution of patients among the CGMH risk groups differed between the CGMH and current cohorts; i.e., 26.4% and 11.3% of patients in the CGMH cohort were allocated to the low and very-high risk groups [9], respectively, in contrast with 5.8% and 22.0%, respectively, in the current cohort. Despite these discrepancies, the CGMH model has been validated as an accurate survival predictive tool for older patients with gastrointestinal cancer.

The original CGMH model revealed the superiority of survival prediction as comparable to that of tumor stage and Charlson comorbidity index [9]. However, we did not compare the performance of the CGMH model to other risk models in the current study. Therefore, it would be an important direction for future research to compare the CGMH model with the other models.

The strength of this study included its prospective designused to externally validate the performance of the CGMH model in the prediction of survival outcome and risk of postoperative complications in geriatric patients with cancer undergoing elective abdominal surgery. However, some limitations of this study merit further discussion. First, half of our patients had colorectal cancer, whereas the remaining patients had HPB and gastric cancer. Although tumor site was one of the scoring items in the CGMH model, different surgical procedures and the extent of vital organ removal of malignancies may induce a large variability in the evaluation of survival outcomes and postoperative complications. Nonetheless, in this study, the CGMH model displayed survival discriminative ability in the subgroup analysis of different cancer types, which was performed to eliminate the effect of cancer type. Second, the CGMH model was developed to predict 1-year survival outcomes for all solid cancer types whereas only gastrointestinal cancer was selected for external validation in this study. As a time-consuming setting in the prospective study, enrolling all cancer types in the current study is difficult. This study enrolled patients with gastrointestinal cancers because these cancer types were the riskiest cancer after surgery in the original CGMH model. Third, all patients underwent curative-intent and elective surgeries in this study; therefore, the association between the CGMH model and postoperative complications should be interpreted with caution in those who undergo palliative resection or non-elective surgery. Finally, and most importantly, although primary surgeons were aware of the CGMH model results prior to cancer surgery, no standard consensus on interventional strategy and optimal perioperative care was reached among the surgeons for patients with poor prognosis in this study. Further large-scale studies combining the CGMH model with standard interventional strategies and perioperative care are necessary to

enhance perioperative care quality and improve long-term survival outcomes in patients with poor prognosis after cancer surgery.

Conclusions

This was a prospective cohort study conducted to externally validate the performance of the CGMH model in the discrimination of surgical mortality risk after cancer surgery. Our results showed that the CGMH model accurately predicted 1-year mortality, long-term survival probability, and the risk of adverse surgical outcomes in older adults with cancer undergoing elective abdominal surgery. Our study justifies prospective use of the CGMH risk model to predict the survival outcomes and safety profiles of cancer surgery in older patients.

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Disclosure of conflict of interest

None.

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Supplementary Table 1. Subgroup analysis for one-year postoperative mortality based on CGMH risk group by different cancer type

Cancer type	CGMH risk group	One-year mortality event/ number of patient (%)	Odds ratio (95% CI)	*P*-value
Overall (n=345)	Low or intermediate	3/156 (1.9%)	1 (reference)	
	High	16/113 (14.2%)	3.73 (2.11-6.57)	<0.001
	Very-high	24/76 (31.6%)	10.1 (5.84-17.6)	<0.001
Colorectum (n=179)	Low or intermediate	1/92 (1.1%)	1 (reference)	
	High	6/56 (10.7%)	3.51 (1.42-8.71)	0.007
	Very-high	5/31 (16.1%)	13.8 (5.81-32.8)	<0.001
HPB or stomach (n=166)	Low or intermediate	2/64 (3.1%)	1 (reference)	
	High	10/57 (17.5%)	3.50 (1.69-7.26)	0.001
	Very-high	19/45 (42.2%)	7.21 (3.53-14.7)	<0.001

HPB, Hepatico-Pancreatico-Biliary.

Supplementary Table 2. Adverse surgical outcomes according to CGMH prognostic group

Outcome	Total cohort (n=345)	Low risk (n=20)	Intermediate risk (n=136)	High risk (n=113)	Very-high risk (n=76)	P for trend
LOS, median (IOR)	14 (10-22)	9 (8-11)	12 (9-21)	15 (11-23)	19 (11-27)	0.003
30-day readmission, n (%)	38 (11.0)	1 (5.0)	13 (9.6)	14 (12.4)	10 (13.2)	0.66
Any major complication, n (%)	50 (14.5)	0	18 (13.2)	17 (15.0)	15 (19.7)	0.044
ICU stay, n (%)	70 (20.3)	0	21 (5.4)	26 (23.0)	23 (30.3)	0.001
In-hospital death, n (%)	9 (2.6)	0	0	6 (5.3)	3 (3.9)	0.011

Abbreviations: ICU, Intensive Care Unit; IQR, Interquartile Range; LOS, Length Of Hospital Stay.