Clinics of Oncology

Clinical Paper

ISSN: 2640-1037 | Volume 6

A CT-Based Nomogram for Preoperative Prediction of Synchronous Peritoneal Metastasis in Colorectal Cancer

Wu Z[1#], Cao W[2#], Wu L[4#], William GM[5], Cai J[1,2,3], Zhang W[3], Chen W[1], Wang H[1,2,3,*] and Yuan Z[1,2,3,*]

[1]Department of Colorectal Surgery, Guangdong Institute of G astroenterology,

[2]Guangdong Provincial Key Laboratory of Colorectal and Pelvic Floor Disease,

[3]Guangdong Research Institute of Gastroenterology, The Sixth Affiliated Hospital of Sun Yat-Sen University, Guangzhou, China.

[4]Department of Radiology, People's Hospital of Guangdong Province, Guangzhou, China.

[5]Clinical Research Division, Fred Hutchinson Cancer Research Center, 1100 Fairview Ave N, D4-100, Seattle, WA 98109, USA

#Wu Z, Cao W, Wu L are co-first authors

[*]Corresponding author:

Hui Wang and Zixu Yuan,
Department of Colorectal Surgery, The Sixth Affiliated Hospital of Sun Yat-Sen University, No. 26 Yuancun erheng Road, Guangzhou 510655, China, Fax: +86-20-3825-4052;
Tel: +86-188-2010-7381;
E-mail: wang89@mail.sysu.edu.cn/ yuanzx5@mail.sysu.edu.cn

Received: 10 Sep 2022
Accepted: 20 Sep 2022
Published: 25 Sep 2022
J Short Name: COO

Citation:

Wu Z, Cao W and Wu L. A CT-Based Nomogram for Preoperative Prediction of Synchronous Peritoneal Metastasis in Colorectal Cancer . Clin Onco. 2022; 6(11): 1-9

1. Introduction

Colorectal Cancer (CRC) is the third most common cancer with estimated 1000,000 of new cases worldwide each year, ranking the third cause of cancer-related death [1]. Peritoneal Metastasis (PM) is considered to be a terminal stage of CRC metastasis with unfavorable fatal outcome [2, 3]. The incidence of synchronous PM is about 5-10% of CRC at the initial diagnosis, while 5% of PM are presented with metachronous PM after radical resection, and approximately 25-44% of patients occur in recurrent disease [2]. Recently, Cytoreductive Surgery (CRS) and hyperthermic intraperitoneal chemotherapy (HIPEC) become popular options and are widely adopted for treating PM in many centers worldwide and the median OS increase to 42 months with this treatment [2,4,5].

Early diagnosis of synchronous PM with a Peritoneal Cancer Index (PCI) < 20 points, can increase the probability of complete CRS procedure [2, 4]. If CRS is incomplete, namely palliative surgery in late-stage PM, the median OS is less than 10 months [2, 6]. Palliative surgery comes with high mortality and substantial hospitalizations and limited survival, especially those with poor prognostic features like ascites or palpable masses with a median survival of 36 days, while early PM with favorable prognostic features obtained a median survival of 154 days [3, 7].

The current imaging tools are not sensitive enough to detect micro PM lesion <5 mm, including contrast-enhanced CT (only 11% of sensitivity), MRI (easily affected by breathing movement) and PETCT (limited by expensive medical afford) [8]. Many patients with PM of gastric or colorectal cancer were firstly diagnosed with negative CT scan, but later were confirmed with PM upon laparoscopic exploration [8, 9]. Integrated analysis of extracted PM features are still useful for radiologists to increase the diagnostic power and avoid to miss micro metastatic sites of PM in high-risk patients, such as T4 stage, peritoneal patch shadow and enhanced degree of tumor, thickened greater omentum, ascites, pelvic nodules, and distant metastasis site under contrast-enhanced CT scans [3, 10]. Recently, Dong et al reported a nomogram of CT phenotypes including both primary tumor and nearby peritoneum and Lauren type for prediction of occult PM in advanced gastric cancer. The accuracy of this nomogram yielded an AUC of >0.9 for excellent prediction of occult PM [9].

In this study, we have developed a CT-based nomogram for preoperative prediction of synchronous PM. Clinical parameters and PM-specific features under contrast-enhanced CT scans were extracted and analyzed by Boruta algorithm [11]. Finally, five PM specific features including cT stage, tumor location, distant metastatic sites, thickened greater omentum and pelvic nodules were enrolled into this CT-based model. This CT-based nomogram provides a potential noninvasive tool for early detection of PM, which

will avoid unnecessary laparoscopic exploration or laparotomy and start systemic chemotherapy earlier.

2. Patients and Methods

2.1. Patients

The patients with or without PM of CRC were screened from our territory medical center between January 2017 and May 2018. Our hospital is a high-volume of gastrointestinal specialized center, with more than 3000 colorectal surgeries of cancer every year. The clinicopathological parameters and survival data at follow-up were collected from one prospective database of CRC, which was well-maintained by professional personnel. The contrast-enhanced CT images from each patient were extracted by radiologists, which were stored in original format in the department of imaging. The 2009 TNM staging system was used to make radiological and pathological staging. The study protocol was approved by local ethical committee of the Sixth Affiliated Hospital of Sun Yat-Sen University (China). The patient's informed consent was obtained before they were enrolled into the prospective database.

2.2. Inclusion and Exclusion criteria

Inclusion criteria: (1) patients with preoperative contrast-enhanced CT scans of primary tumor in our institute, (2) patients with synchronous PM or non-PM of CRC origin were identified by pathological reviews of biopsied specimens during exploration or surgical resected specimens after CRS procedure.

Exclusion criteria: patients whose original CT scans were not preserved or not available in our hospital were excluded.

2.3. The acquisition of PM specific features

All enrolled patients underwent contrast-enhanced CT scans with a high-resolution of 640-slice spiral CT scanner in our medical center (Toshiba Aquilion ONE) before surgical resection of primary tumor. The parameters of CT scanner were listed as follows: 120kV, Auto mA, a matrix of 512 X 512 and a gantry rotation time of 0.5s. Nonionic contrast (Ultravist 370, Bayer healthCare) was injected through intravenous administration at the rate of 1.5ml/s. Arterial and vein phase images were obtained at the 25s and 60s, respectively [12].

PM-specific features were extracted from venous phase of preoperative contrast-enhanced CT images by two independent radiologists. Any disagreements were resolved by discussion and consistent consensus was reached. The specific features of PM in CT scans include thirteen variables as follows: tumor location (left or right sided), cT stage, invasion of adjacent organs (T4b), N status, peritoneal patch shadow, enhanced degree of tumor, necrosis, perforation, metastatic sites of PM, distant metastasis, ascites, thickened greater omentum, and pelvic nodules (Figure 1).

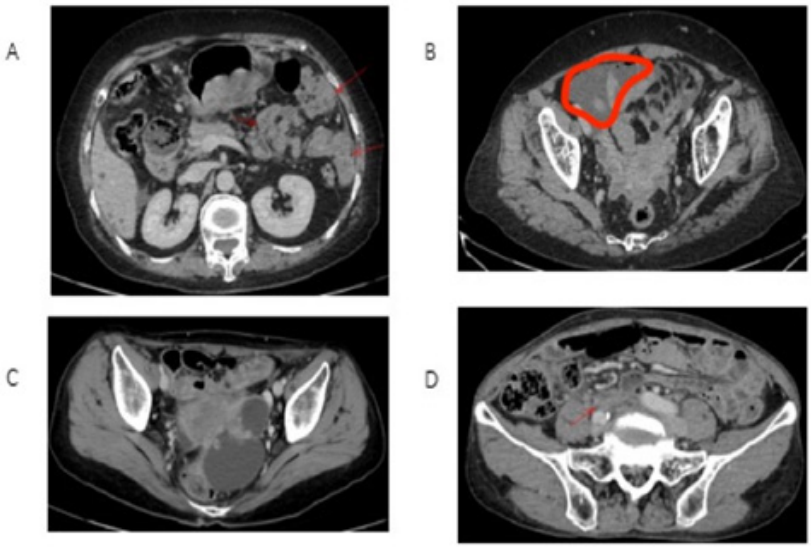

Figure 1: The classical features of PM in contrast-enhanced CT scans. A. T4b stage in which tumor invades to local peritoneum; B. Pelvic ascites; C. Ovarian metastasis; D, Invasion of urine system in late PM.

2.4. The construction of CT-based model

The flow diagram of the constructions of CT-based model and nomogram was shown in Figure 2. Training images were collected to construct one CT-based model. Boruta algorithm was suitable for high-dimensional data to select PM-specific features with non-zero coefficients from 92 cases in the training set [12]. Firstly, PM-specific features were selected by Boruta algorithm, including tumor location, cT stage, enhanced degree, peritoneal metastatic sites, thickened greater omentum and pelvic nodules. A formula was then generated by using a linear combination of these PM-specific features by forward step regression. Akaike Information Criteria (AIC) principles were used to further screen variables. Finally, five variables were enrolled into the CT-based model, including tumor location, cT stage, distant metastasis, thickened greater omentum and pelvic nodules. The mathematic formula of multivariate logistic regression was shown as follows:32.892+1.51* cT stage + 1.884* tumor location +20.447* distant metastatic sites– 19.898 *thickened greater omentum – 20.222* pelvic nodules.

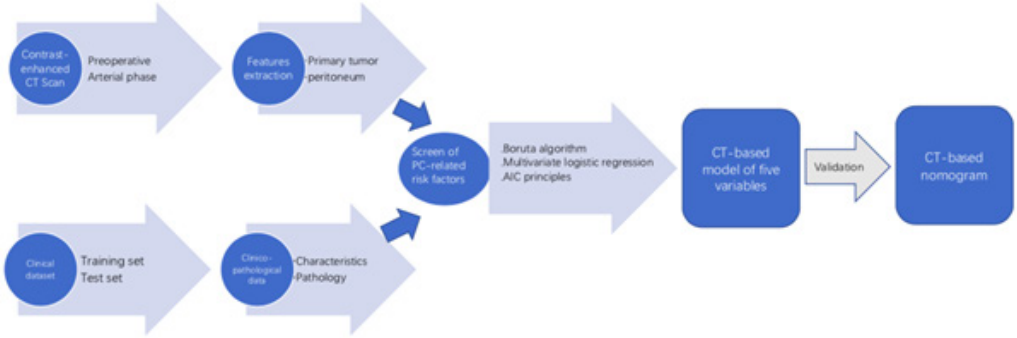

Figure 2: The flow diagram in constructions of CT-based model and nomogram.

2.5. The validation of CT-based model

To evaluate the performance of constructed CT-based model, the venous phase of CT images in the test set were prepared. Several criteria were selected to evaluate the accuracy of the CT-based model to discriminate PM from non-PM. The accurate rate of CT-based model was calculated as follows: the number of PM patients diagnosed correctly by CT-based model/all CRC patients with PM. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of CT-based model were calculated as follows: sensitivity, number of PM patients diagnosed correctly / all cases with PM; specificity, number of non-PM patients diagnosed correctly /all patients with non-PM; PPV, number of PM patients diagnosed correctly / all patients diagnosed with PM; NPV, number of non-PM patients diagnosed correctly / all patients diagnosed with non-PM [13].

2.6. The construction and assessment of CT-based nomogram

The CT-based model and clinical parameters were assessed in the multivariate logistic regression model in the training set. A CT-based nomogram was then constructed based on the results of multivariate logistic regression model in the training set. A risk score was created by the formula of CT-based model to reflect the individual risk of PM. The reference level of variable was assigned to "0". The sum of these variables was matched to a risk score of PM for each patient [11]. The calibration of CT-based nomogram was then assessed by calibration curves in the training set and test set. To assess the performance of this nomogram, a radiological score was calculated for each patient. Furthermore, to estimate the clinical utility of this CT-based nomogram, decision curve analysis (DCA) was created by calculating the net benefits of threshold probabilities in the combined training and test set [12].

2.7. Statistical Analysis

All continuous variables were compared by Student t test and Chi square test was performed for categorial variables. For parameters not normally distributed, non-parametric test was conducted. Logistic regression model was constructed and analysis was performed to identify risk factors of PM. A $P<0.05$ (two-sided) was considered to be statistically significant. All of these data were analyzed by using R statistical software v3.3.1 [11].

3. Results

3.1. Demographics and Characteristics

After screening of about 3000 CRC patients between January 2017 and February 2018, 250 cases with synchronous PM (about 8%) were identified. After exclusion, 74 PM patients with preoperative contrast-enhanced CT scans were enrolled. Another 96 continual CRC patients without PM were selected as control. Both PM and non-PM patients were divided into training set and test set by the time point of February, 2018. The training set consisted of 92 CRC (41 PM and 51 non-PM) who conducted CT scans before February 28, 2018, while the test set consisted of 78 CRC patients (33 PM and 45 non-PM) after February 28, 2018. The baseline characteristics of enrolled 170 patients were listed in Table 1. The parameters of PM or non-PM patients were compared in the training set and test set, respectively. T4 stage, distant metastasis site, increased preoperative CEA level, peritoneal patch shadow and enhanced degree of tumor, thickened greater omentum and pelvic nodules were identified as the risk factors of PM both in the training and test sets. Other potential variable didn't show significant differences in CRC patients with or without PM (Table 1).

Table 1: The baseline characteristics of 170 enrolled CRC patients in the training set and test set.

Characteristic	Training set			Test set		
	PM (n=41)	non-PM (n=51)	*P* value	PM (n=33)	non-PM (n=45)	*P* value
Age						
<50	14	11	**0.009**	12	7	**0.076**
50-69	19	38		18	29	
>70	8	2		3	9	
Gender (M/F)						
Male	27	30	**0.396**	23	26	**0.282**
Female	13	21		10	19	
Location of primary tumor			**0.02**			**0.033**
Right sided	20	37		19	15	
Left sided	21	14		14	30	
Pre-op blood CEA						
>5 ng/ml	24	19	**0.038**	18	15	**0.061**
<5 ng/ml	16	31		15	30	
T stage						
T1	0	1	**<0.001**	0	0	**<0.001**
T2	0	4		0	7	
T3	12	39		6	33	
T4a	19	4		19	5	
T4b	10	3		8	0	
Lymph node metastasis						
positive	26	27	**0.312**	28	23	**0.002**
negative	15	24		5	22	
Distant metastasis						
no	20	44	**0.003**	15	43	**<0.001**
liver	14	5		17	2	
lung	1	1		0	0	
liver+lung	5	1		1	0	
bone	1	0		0	0	
Peritoneal patch shadow			**0.005**			**<0.001**
Yes	16	7		25	4	
No	25	44		8	41	
Enhanced degree of tumor			**<0.001**			**<0.001**
Yes	13	48		17	42	
No	28	3		16	3	
Necrosis						
Yes	3	2	**0.475**	16	5	**<0.001**
No	38	49		17	40	
Perforation						
Yes	3	0	**0.085**	0	0	-
No	38	51		33	45	
Thicken greater omentum			**<0.001**			**<0.001**
Yes	19	0		19	0	
No	22	51		13	45	
Pelvic planted nodes						
Yes	16	0	**<0.001**	6	0	**0.003**
No	25	51		27	45	
Ascites						
Yes	0	2	**0.2**	14	4	**0.001**
No	41	49		19	41	

*P < 0.05 indicates significant difference. PM-peritoneal metastasis; CEA, carcinoembryonic antigen.

3.2. The performance of routine CT by radiologists

We firstly assessed the performance of routine contrast-enhanced CT by two independent radiologists. In the total set of 170 patients, the AUC of routine CT by one senior radiologist was 0.791 (95% CI: 0.716, 0.865) (Figure 3A). The sensitivity at cutoff value of 0.5 was 58.1% and the specificity was 100%. In the training set of 92 cases, the AUC was 0.793 (0.692, 0.893). The sensitivity was 58.5% and the specificity was 100% (Figure 3B). In the test set of 78 cases, the AUC by senior radiologist was 0.788 (0.675, 0.900). The sensitivity was 57.6% and the specificity was 100% (Figure 3C).

For the performance of junior radiologist, in the total set, the AUC of routine CT was 0.780 (0.704, 0.856) (Figure 3D). The sensitivity at cutoff value of 0.5 was 58.1% and the specificity was 97.9%. In the training set, the AUC was 0.787 (0.699, 0.875). The sensitivity was 57.4% and the specificity was 100% (Figure 3E). In the test set, the AUC by senior radiologist was 0.750 (0.593, 0.907). The sensitivity was 60.0% and the specificity was 90.0% (Figure 3F).

The main cause of false positive cases (n=32) for senior radiologist was stage T4a-b tumors or large size (>5mm). It is misdiagnosed with PM for suspicious of invasion to adjacent peritoneum under CT scans, but actually no PM was identified during operational exploration and postoperative pathological review. The causes of false negative cases (n=25) included small metastatic nodules in the abdominal wall, intestinal mesentery or greater omentum.

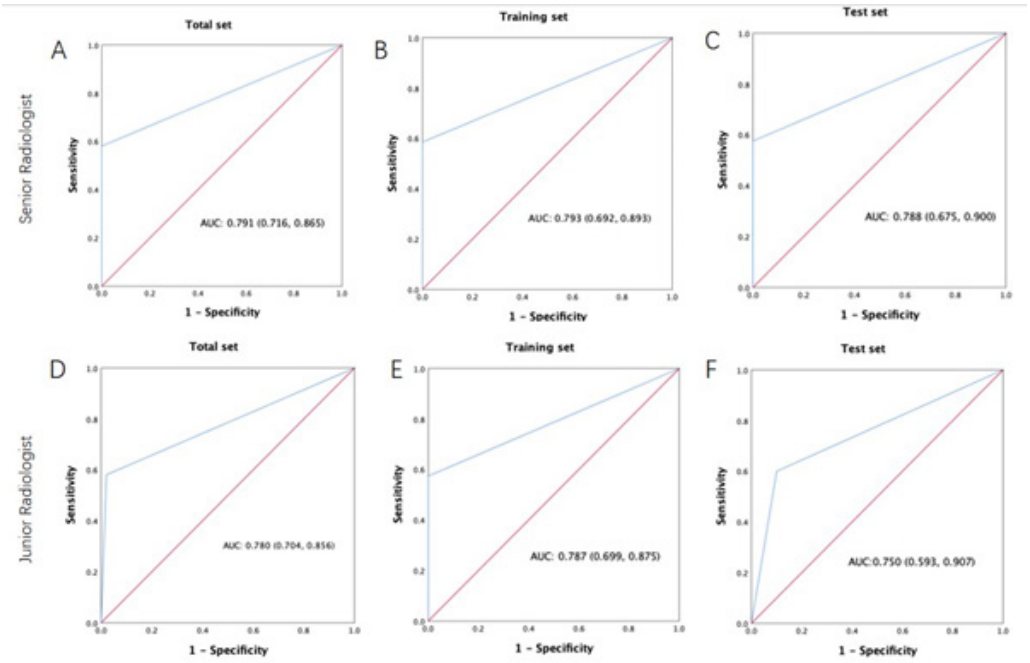

Figure 3: The performance of routine CT by radiologists. (A)-(C) the performance of senior radiologist;(D)-(F) the performance of junior radiologist.

3.3. The prediction of CT-based model

In the training set, the AUC of CT-based model was 0.929 (95% CI: 0.764-0.946). The sensitivity was 73.2% and the specificity was 98.3%. The PPV was 82.26%, while the NPV was 100% (Figure 4A). In the test set, the AUC was 0.855 (0.764-0.946). The sensitivity of CT-based model was 72.7% and the specificity was 93.3%. The PPV was 82.35%, while the NPV was 88.89% in the test set (Figure 4B). These results showed superior performance of CT-based model than routine contrast CT both by senior radiologist (AUC :0.791) and junior radiologist (AUC: 0.780) in detection of PM.

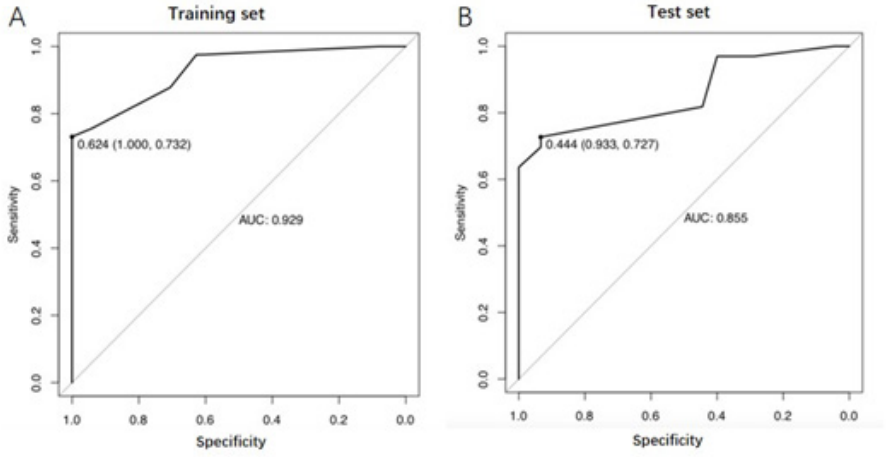

Figure 4: The ROC shows high predicted power of CT-based model in diagnosis of PC. (A) the AUC in the training set in ROC curve was 0.929（95% CI: 0.764-0.946）. (B) the AUC in the test set was 0.855（95% CI: 0.764-0.946.

3.4. The performance of CT-based nomogram

After the construction of CT-based model, we have created a CT-based nomogram to incorporate these five variables by the formula, which included cT stage, tumor location (right or left sided), distant metastatic sites, thickened greater omentum and pelvic nodules (Figure 5). Through this nomogram, we can calculate PM risks for every patient. For example, if a patient was diagnosed with T4a stage (42 points) located in the right colon (0 point). The contrast-enhanced CT scan showed hepatic metastasis (8 points) and thickened greater omentum (94 points) without pelvic nodules (0 point). Then the total score of this patient was 144 points. The matched risk of PM was >0.999 and the patient was at very high risk of PM.

To evaluate the performance of this CT-based nomogram, we have created calibration curves. The results showed the blue lines were very closer to the ideal prediction lines (diagonal line) both in the training set and test set, especially in test set, which indicated very high predicted accuracy of this CT-based nomogram in diagnosis

of PM (Figure 6A, C). To further evaluate the diagnostic power of this nomogram, DCA curves were created and showed CT-based nomogram could add more benefits in PM prediction for clinical decisions both in the training set and test set (Figure 6B, D).

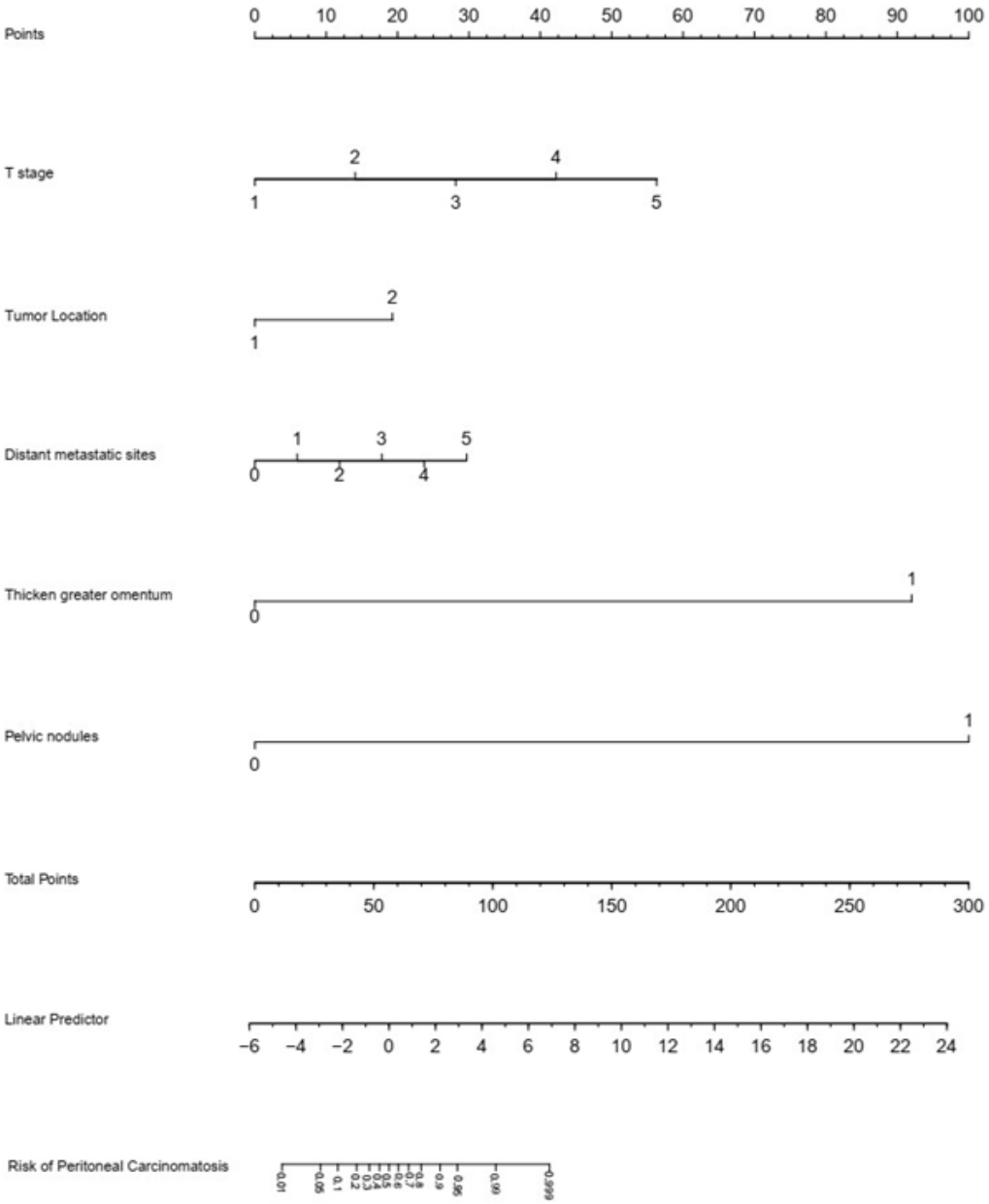

Figure 5: The CT-based nomogram for the risk prediction of PC. The referred score of each variable in this nomogram was 100 points. Each down line can be matched to scores according to the above reference score. cT stage of 1, 2, 3, 4a, 4b represents 1-5 in the line, respectively; locations of 1 and 2 represent right and left sided tumor; distant_ metastasis_ sites were classified as no (0), liver (1), lung (2), liver+lung (3), bone (4), and brain (5); the status of both thickened greater omentum and pelvic nodules were yes (1) or no (0). The total score was 300 points. The sum of five variables represent the score of each patient, which can be matched to the risk of PC.

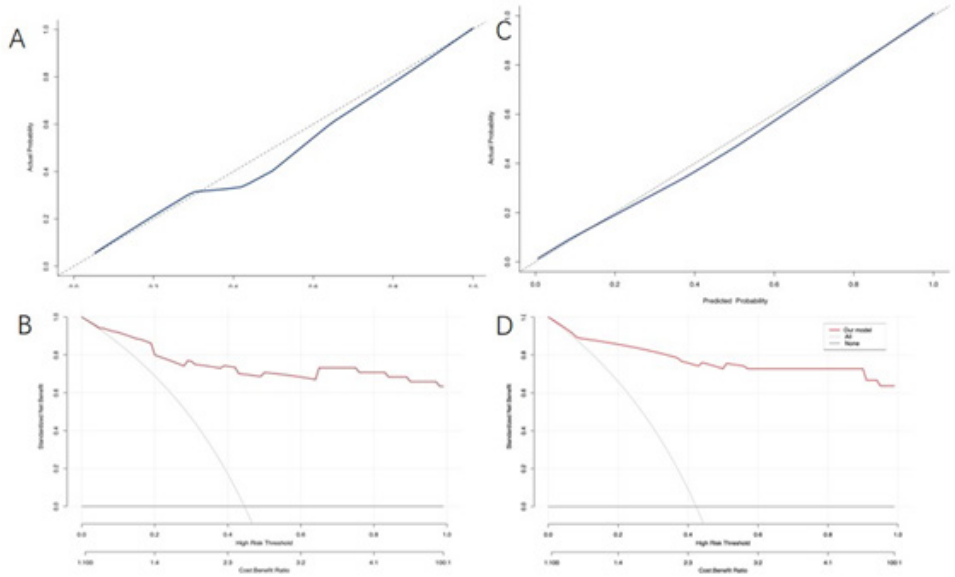

Figure 6: The calibration curves and decision curves of CT-based nomogram for the prediction of PC in CRC. (A-D) Calibration curve and decision curve of CT-based nomogram in the training set (A-B) and the test set (C-D). (A, C) The calibration curves describe calibration of CT-based nomogram in agreement between predicted risk (x-axis) and real risk (y-axis) of PC. In this study, the blue line very closer to the ideal prediction indicates very high prediction accuracy of CT-based nomogram.

(B, D) In the decision curve, the threshold probability is where expected benefit of treatment is equal to expected benefit of avoiding treatment. The study shows this CT-based nomogram can add more benefits than treating either all or no patients. The y-axis represents the net benefit, while x-axis represents the threshold probability. Red line, CT-based nomogram; gray line, hypothesis that no patients have PC.

3.5. PM with lower PCI score

The PCI scores were also calculated in preoperative CT scans of patients with PM by two radiologists. The PCI scores of Sugarbaker (range 0-39 of 13 regions) were used to quantify the extent and volume of PM under CT scans [14]. 56 of 74 (76%) patients with PM had PCI <20, where HIPEC and peritonectomy could provide survival benefit [15]. The remaining 18 of 74 (24%) patients with PM obtained PCI>20 with more extensive disease. These above results indicated that our CT-based nomogram was also reliable for detection of PM with lower PCI.

4. Discussion

PM is a well-known negative prognostic factor for CRC patient. Although current CRS plus HIPEC is recommended and implemented in many medical centers and have improved the prognosis, 5-year OS of PM is still less than 10% [11, 16]. Recently, PRODIGE-7 trial showed HIPEC did not add additional survival benefit (about 41 months) after CRS in PM [5]. In addition, COLOPEC trial also found HIPEC can't improve survival after curative resection in high-risk or T4 stage of colon cancer [17]. These studies doubt the efficacy of HIPEC in PM and indicated the importance of complete CRS to extend survival. Early detection of PM in local stage, solitary pelvic nodules, or ovarian metastasis in female can increase the possibility of complete CRS. If high risk of PM were diagnosed preoperatively, these patients are appropriate for neoadjuvant chemotherapy and may bring survival benefits. However, the accuracy of contrast CT scan is not sensitive enough to detect small metastatic nodules <0.5 cm, while the sensitivity increased to 97% for detection of large tumor size >5cm [8, 18]. MRI with diffusion-weighted imaging (DWI) have better detection of inoperable distant metastases than CT, but also limited to detect small nodules in the abdominal cavity [19].

Dong et al reported a CT nomogram to identify occult PM in advanced gastric cancer with AUC >0.9 by combination of CT phenotypes of primary tumor and nearby peritoneum [9]. Mo et al built a clinical nomogram based on tumor site, histological type, age and T4 stage with an AUC of 0.777 for prediction of synchronous PM in CRC [20]. Therefore, new predictive models by mathematic algorithms for predicting early PM are critical, which will be complimentary to current imaging devices.

In this study, we have developed a CT-based model and generated a formula through mathematic algorithm of PM specific features, which include cT stage, tumor location, distant metastatic sites, thickened greater omentum and pelvic nodules. This CT-based modelhas shown superior performance (AUC: 0.855) than routine contrast CT by radiologists (AUC: 0.791). The nomogram indicated a very clear stratification between PM and non-PM. This nomogram provides an easy-to-use tool for clinicians to estimate risks of PM upon imputed these preoperative parameters for each patient. The nomogram shows satisfied performance with good calibration curve and DCA curve. Significant benefit of this nomogram was observed in a wide range of threshold probabilities to support clinical decision.

There are several strengths of this nomogram in the preoperative prediction of PM. The routine contrast-enhanced CT to detect PM

is limited with general sensitivity 25%-100% and 78%-100% of specificity [8]. In this study, we observed satisfied sensitivity of routine CT to detect large nodules of PM. However, small metastatic nodules in the abdominal wall, cancer nodules in intestinal mesentery or greater omentum are usually neglected by routine contrast CT scans. These conditions are major causes of false negative values. PM-specific features of this CT-based nomogram can aid for detection of small PM nodules. As for false positive value, it usually occurs in a few patients with stage T4a-b or large size tumors (>5 mm). It is misdiagnosed with PM for suspicious of invasion to adjacent peritoneum under CT scans, but no PM was identified during operational exploration and postoperative pathological review. This CT-based nomogram can avoid over diagnosis of PM through integration analysis of primary tumor and adjacent peritoneum.

This CT-based nomogram consists of five variables including cT stage, tumor location, distant metastatic sites, thickened greater omentum and pelvic nodules. All of these variables are available through routine CT. T4 stage, right-sided CRC, PCI >20, and distant metastatic sites are known risk factors of PM and predict poor prognosis in CRC [10, 21]. Our nomogram serves as one noninvasive tool to predict PM preoperatively, which can avoid current invasive procedure of laparoscopic or laparotomic exploration for diagnosis of suspicious PM.

As well as we know, out nomogram is the only one study of preoperative model with CT features to predict individual risk of synchronous PM in colorectal cancer. Predictive models for postoperative recurrence of PM, or oncological prognosis are reported in previous studies [11, 22]. Nagata et al developed a predictive model of postoperative PM after curative resection with a good discrimination of 0.83, which consisted of cT stage, N stage, number of lymph node, CEA and bowel obstruction [11]. We believe the estimation of individual risk of PM before CRS is crucial, because early detection of PM can increase the possibility of complete CRS and avoid unnecessary exploring laparotomy and start systemic chemotherapy earlier. Therefore, our nomogram is an easy-to-use tool both for clinicians to make surgical plans and patients to select appropriate treatments, such as CRS or neoadjuvant chemotherapy, according to calculated individual risks of PM.

The limitations of this study include lacking of external validation test for this CT-based model. As the incidence of synchronous PM in CRC is only 5% and the percent of patients with preoperative CT scans stored in one medical center is low. Multicenter validation or even prospective randomized clinical trials to test our nomogram are needed to provide higher evidence. Secondly, the radiologists are initially not blinded to the pathological report, which may bring potential bias. We use the test set to minimize the bias. In addition, only thirteen PM features of contrast-enhanced CT scans were extracted and may miss other important features. A radiomic nomogram to extract more extensive features to construct a more accurate model to predict PM before surgery is on the way in our further studies. Lastly, surgical PCI scores are not available due to the retrospective study and PCI score of CT images was obtained in PM, which will bring potential bias.

In conclusion, our CT-based nomogram shows favorable preoperative predictive power for synchronous PM in CRC. It is an easy-to-use non-invasive tool for clinicians and patients to calculate individual risks of PM.

5. Funding

This study was supported by the National Natural Science Foundation of China grant (No. 82103038) and Guangzhou Science and Technology Program (202201011360), and National Key Research and Development Program of China (2021YFC2101700), Sun Yat-sen University Clinical Research 5010 Program (grant numbers 2017008 and 2019021).

References

1. Siegel RL, Miller KD, Jemal A. Cancer statistics. CA: a cancer journal for clinicians. 2019; 69(1): 7-34.
2. Razenberg LG, van Gestel YR, Creemers GJ, Verwaal VJ, Lemmens VE, de Hingh IH. Trends in cytoreductive surgery and hyperthermic intraperitoneal chemotherapy for the treatment of synchronous peritoneal carcinomatosis of colorectal origin in the Netherlands. European journal of surgical oncology: the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology. 2015; 41(4): 466-471.
3. Paul Olson TJ, Pinkerton C, Brasel KJ, Schwarze ML. Palliative surgery for malignant bowel obstruction from carcinomatosis: a systematic review. JAMA surgery. 2014; 149(4): 383-392.
4. Wang L, Cai J, Qin QY. Treatment for peritoneal metastasis of colorectal cancer. Zhonghua Wai Ke Za Zhi. 2018; 56(8): 569-572.
5. Quenet F, Elias D, Roca L, et al. A UNICANCER phase III trial of hyperthermic intra-peritoneal chemotherapy (HIPEC) for colorectal peritoneal carcinomatosis (PC): PRODIGE 7. Journal of Clinical Oncology. 2018; 36(18_suppl): LBA3503-LBA3503.
6. Swellengrebel HA, Zoetmulder FA, Smeenk RM, Antonini N, Verwaal VJ. Quantitative intra-operative assessment of peritoneal carcinomatosis - a comparison of three prognostic tools. European journal of surgical oncology: the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology. 2009; 35(10): 1078-1084.
7. van Ooijen B, van der Burg ME, Planting AS, Siersema PD, Wiggers T. Surgical treatment or gastric drainage only for intestinal obstruction in patients with carcinoma of the ovary or peritoneal carcinomatosis of other origin. Surgery, gynecology & obstetrics. 1993; 176(5): 469-474.
8. Koh JL, Yan TD, Glenn D, Morris DL. Evaluation of preoperative computed tomography in estimating peritoneal cancer index in colorectal peritoneal carcinomatosis. Annals of surgical oncology. 2009; 16(2): 327-333.

9. Dong D, Tang L, Li ZY, et al. Development and validation of an individualized nomogram to identify occult peritoneal metastasis in patients with advanced gastric cancer. Annals of Oncology. 2019; 30(3): 431-438.
10. Honore C, Goere D, Souadka A, Dumont F, Elias D. Definition of patients presenting a high risk of developing peritoneal carcinomatosis after curative surgery for colorectal cancer: a systematic review. Annals of surgical oncology. 2013; 20(1): 183-192.
11. Nagata H, Ishihara S, Oba K, et al. Development and Validation of a Prediction Model for Postoperative Peritoneal Metastasis After Curative Resection of Colon Cancer. Annals of surgical oncology. 2018; 25(5): 1366-1373.
12. Wu S, Zheng J, Li Y, et al. A Radiomics Nomogram for the Preoperative Prediction of Lymph Node Metastasis in Bladder Cancer. Clinical cancer research: an official journal of the American Association for Cancer Research. 2017; 23(22): 6904-6911.
13. Horie Y, Yoshio T, Aoyama K, et al. The diagnostic outcomes of esophageal cancer by artificial intelligence using convolutional neural networks. Gastrointest Endosc. 2018.
14. Jacquet P, Sugarbaker PH. Clinical research methodologies in diagnosis and staging of patients with peritoneal carcinomatosis. Cancer Treat Res. 1996; 82: 359-374.
15. Elias D, Gilly F, Boutitie F, et al. Peritoneal colorectal carcinomatosis treated with surgery and perioperative intraperitoneal chemotherapy: retrospective analysis of 523 patients from a multicentric French study. Journal of clinical oncology: official journal of the American Society of Clinical Oncology. 2010; 28(1): 63-68.
16. Garrett CR, George B, Viswanathan C, et al. Survival benefit associated with surgical oophorectomy in patients with colorectal cancer metastatic to the ovary. Clinical colorectal cancer. 2012; 11(3): 191-194.
17. Klaver CEL, Wisselink DD, Punt CJA, et al. Adjuvant hyperthermic intraperitoneal chemotherapy in patients with locally advanced colon cancer (COLOPEC): a multicentre, open-label, randomised trial. Lancet Gastroenterol Hepatol. 2019; 4(10): 761-770.
18. Chang-Yun L, Yonemura Y, Ishibashi H, et al. Evaluation of preoperative computed tomography in estimating peritoneal cancer index in peritoneal carcinomatosis. Gan to kagaku ryoho Cancer & chemotherapy. 2011; 38(12): 2060-2064.
19. Dresen RC, De Vuysere S, De Keyzer F, et al. Whole-body diffusion-weighted MRI for operability assessment in patients with colorectal cancer and peritoneal metastases. Cancer Imaging. 2019; 19(1): 1.
20. Mo S, Dai W, Xiang W, Li Q, Wang R, Cai G. Predictive factors of synchronous colorectal peritoneal metastases: Development of a nomogram and study of its utilities using decision curve analysis. International journal of surgery (London, England). 2018; 54(Pt A): 149-155.
21. Kyang LS, Alzahrani NA, Alshahrani MS, Rahman MK, Liauw W, Morris DL. Early recurrence in peritoneal metastasis of appendiceal neoplasm: Survival and prognostic factors. European journal of surgical oncology: the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology. 2019.
22. Kawai K, Sunami E, Yamaguchi H, et al. Nomograms for colorectal cancer: A systematic review. World journal of gastroenterology. 2015; 21(41): 11877-11886.