World Journal of Surgical Oncology

RESEARCH

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Individualized prediction of stent patency in malignant colonic obstruction: development and validation of a prognostic model

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Abstract

Purpose To develop and validate a predictive model for stent patency following a palliative self-expandable metallic stent (SEMS) for primary malignant colonic obstruction.

Methods Patients with primary malignant colonic obstruction who underwent SEMS treatment were included in this study. One retrospective set ($N=121$) was used to develop and validate the predictive model. The clinical features were collected and subjected to Cox regression analyses. The final predictive model was displayed as a nomogram, which was validated in an independent set ($N=36$).

Results The clinical prognostic model was composed of pre-chemotherapy ($P<0.001$), time of obstruction ($P=0.005$), and post-chemotherapy ($P<0.001$). The time-dependent area under the curve were 0.898 at 30-day, 0.778 at 90-day, 0.728 at 180-day, and 0.844 at 360-day in the training set; and 0.654 at 30-day, 0.745 at 90-day, 0.777 at 180-day, and 0.740 at 360-day in the validation set. Moreover, this easy-to-use and individualized nomogram was exclusively applied to predict stent patency and showed a favorable prognostic performance in the training and validation sets.

Conclusion The nomogram developed in this study accurately predicts stent patency and shows promise for personalized SEMS management. However, external validation must be prioritized before clinical implementation to ensure generalizability and safety.

Keywords Primary malignant colonic obstruction, Stent patency, Nomogram, Prognosis, LASSO Cox regression

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Background

The placement of self-expandable metal stents (SEMS) is widely acknowledged as an effective method for alleviating malignant colorectal obstruction, offering numerous advantages over surgical interventions such as a reduced early complication rate, improved quality of life, and shorter hospitalization [1–3]. Therefore, SEMS is recommended as the preferred choice for palliative management of malignant colorectal obstruction [4]. Nevertheless, notwithstanding the benefits associated with SEMS, studies suggest an increased occurrence of delayed complications, notably stent occlusion [1], which may result in both physical and emotional distress for the patient. Therefore, it is crucial to devise a robust methodology for the early and precise detection of stent occlusion following the deployment of SEMS. Notably, there is currently a lack of research focused on developing a diagnostic model for stent occlusion.

In the current study, our principal objective was to construct a predictive model employing multivariate Cox regression, integrating clinical, laboratory, and operative features to differentiate stent patency following SEMS. Subsequently, the initial predictive model was represented as a nomogram and further adapted into an innovative scoring system to facilitate practical clinical application.

Materials and methods

Study design and patients

Between September 2014 and October 2023, a retrospective review was conducted on 354 patients who underwent SEMS procedures at our medical center. Inclusion criteria: (1) Patients with malignant colorectal obstruction confirmed by radiology or endoscopy. (2) Patients who decline or cannot undergo surgery receive palliative treatment. Exclusion criteria: (1) Patients with SEMS for bridging to surgery ($N=177$); (2) Extra malignant colorectal obstruction ($N=35$); (3) Patients who was lost to follow-up ($N=8$); (4) Intestinal perforation ($N=8$); (5) Technical failure ($N=5$). Ultimately, 121 patients met the inclusion criteria and were analyzed (Fig. 1).

Candidate risk factors collection

Data on the impact of different clinical and interventional factors believed to influence stent patency were gathered. These factors encompassed patient variables such as: (i) patient parameters, including age, gender, cardiovascular health, time of obstruction, levels of carcinoembryonic antigen (CEA) and white blood cells (WBC); (ii) therapeutic variables, including treatment history, as well as chemotherapy utilization pre and post SEMS procedure; (iii) tumor characteristics, such as tumor location and stage, degree of obstruction, Dmax of obstruction (The maximum diameter of the proximal blocked intestinal segment was assessed using recent computed tomography scans) and length(s), and the presence or absence of peritoneal metastasis, and (iv) interventional practices, including stent expansion rate at day 1 and balloon dilation after SEMS placement.

Endpoints and definitions

The primary endpoint of this study is primary stent patency and its associated factors. Stent patency duration is the time from stent placement to recurrence of symptoms due to stent blockage or migration, confirmed by endoscopy or computed tomography (CT). If no symptoms occurred, stent patency duration was considered equal to survival time [5, 6]. Technical success rate [4], Clinical success rate [3, 7, 8], Degree of obstruction [8], and Stent expansion rate at day 1 [6] were defined as previously described.

Time of obstruction was defined as the time from the associated symptoms (abdominal pain, nausea and/or vomiting, inability to pass stool or flatus) first appeared to SEMS treatment. Dmax of obstruction was defined as the maximum diameter of the proximal blocked intestinal segment.

SEMS procedure

All patients were positioned on the operating table in a supine position, with the perineum disinfected and covered. Liquid paraffin oil was applied to the anus to reduce discomfort from catheter friction. A 0.035-inch-diameter guide wire, 5-French catheter, and 8-French guide catheter were inserted through the anus under fluoroscopy guidance. Contrast agent injected into the catheter for colonographpy to observe the intestine morphology and obstruction site. A hydrophilic guide wire was then passed through the obstruction segment, allowing for determination of the obstruction's location and length through colonographpy. The Zebra guide wire (Boston Scientific) was inserted into the obstruction and used to guide the placement of the Enteral Wallstent (25 mm ×120 mm, Boston Scientific, Marlborough, MA, U.S.A.) or Evolution stent (25 mm ×10 cm or 25 mm ×8 cm, Cook Ireland Ltd., Limerick, Ireland). Support was released once the position was confirmed, and the stent expansion was assessed through reimaging. Technical success was defined as the self-expanding stent effectively covering stenotic regions over 2 cm at both ends after deployment [4].

If stent under-expansion was detected, a 6–8 mm diameter balloon catheter (Admiral; Medtronic, Santa Rosa, CA, U.S.A.) was utilized to dilate it within a constricted area. Once the desired elongation is achieved, the guide wire and catheter are removed. Upon the release of the stent, the patient was required to have a liquid diet.

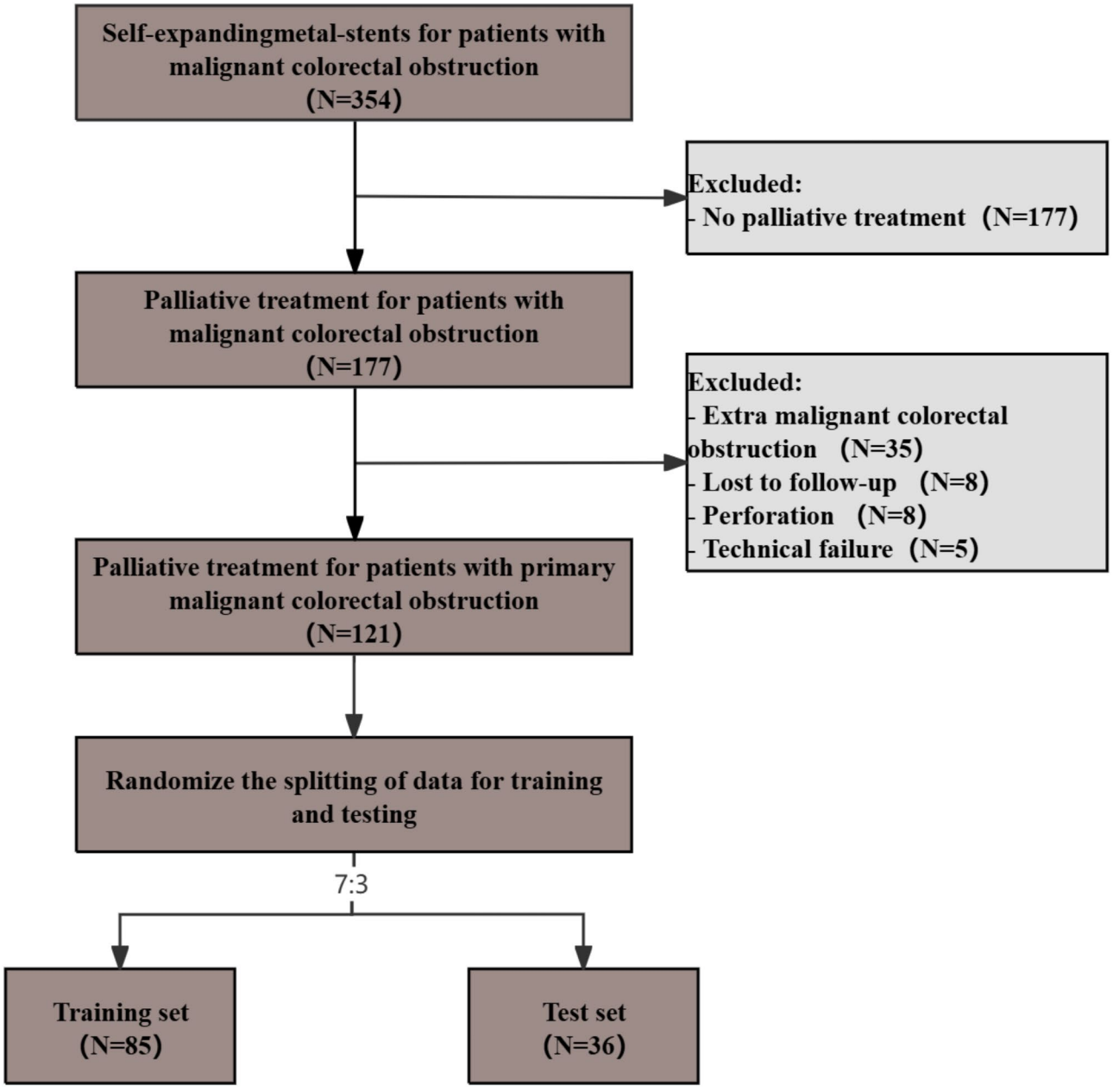

Fig. 1 Schematic of the study design and the selection of the final study cohort

Statistical analysis

Statistical analysis in the study was performed using R version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria). Unless otherwise stated, P value < 0.05 (both sides) was considered significant. Missing values were shown in Supplementary Figure S1. The stent expansion rate after 48 h and Dmax of obstruction after release variables were removed since the probability of missing value was set to 5% [9]. We applied the mice R package to create multiple imputations by chained equations for multivariate missing data [10]. The density maps for the two multivariate imputed variables were shown in Supplementary Figure S2.

Continuous variables were compared using Student's t-test and presented as mean ± SD for normally distributed data, or Wilcoxon signed-rank test and presented as medians with interquartile ranges (IQR) for non-normally distributed data, while categorical variables were shown as frequencies (percentage) and tested with chi-square or Fisher exact tests. Spearman correlation coefficient was used to assess variable correlations, and pairs of covariates with a correlation coefficient > 0.7 were

excluded from multivariate analysis to avoid multicollinearity [11].

Dimensionality reduction was performed through the application of L1 regularization and the Least Absolute Shrinkage and Selection Operator (LASSO) regression, identifying closely associated features. This process yielded a concise model where only select features made substantial contributions to the predictive stent patency, thereby improving the model's interpretive clarity and broader applicability in the training set using the glmnet R package [12, 13]. We found the best cutoff point for the continuous variables using the maxstat R package [14], which identifies the point that is most strongly related to the outcome. Survival curves were estimated using the Kaplan-Meier method and compared using the log-rank test. Multivariate Cox regression analysis was used to identify final prognostic indicators, and a prognostic nomogram and web calculator were created based on independent prognostic factors [15, 16]. Meanwhile, we categorized patients into high and low-risk groups based on the risk score, created calibration curves for the prognostic nomogram, and used time-dependent area under the curve (AUC) to assess its discriminative power. The decision curve analysis (DCA) curves were also used to evaluate the nomogram's utility for decision making across various risk thresholds.

Results

Baseline characteristics

A total of 121 participants were included in this research and 70% ($N = 85$) were randomly assigned to the training set while the remaining participants ($N = 36$) were included in the validation set via stratified random sampling using the caret package in R. This method ensures that key baseline characteristics, such as age, sex, obstruction severity, chemotherapy status, and tumor location, were proportionally distributed between the training and validation sets. A detailed flow diagram of patient selection is listed in Fig. 1. The patients' baseline clinical characteristics in the training and validation sets from the imputed dataset are summarized in Table 1.

Technical and clinical outcomes

Technical success and clinical success rate were 96.0% (121/126) and 95.0% (115/121), respectively. The mean stent patency time was 157.6 days. In this study, 8 patients had colonic perforation. 4 patients had chemotherapy before and after stent placement, while 3 patients did not have chemotherapy before stent placement, which were no statistically significant differences found in the results (Supplementary Table S3, $P = 0.373$).

Predictive factors for stent patency

No effect of multicollinearity in the imputed dataset was detected as shown in Supplementary Figure S3 (all Spearman correlation coefficients were below 0.7), and we plotted the Kaplan-Meier curve for overview of the whole training set (Supplementary Figure S4). During the feature selection process, we fitted a Lasso regression model based on the optimal λ value (Fig. 2A) and selected the λ value with the minimum partial likelihood deviance (0.071, 95%CI: -0.230-0.373) (Fig. 2B). After feature dimensionality reduction, a final selection of 5 clinical features with non-zero coefficients were displayed (Fig. 2C). After determining the prognostic cut-off points for the two continuous variables: Length of obstruction (5.2 cm) and time of obstruction (6.0 days), the Kaplan–Meier curves for the five candidate categorical variables and the log-rank tests ($P < 0.5$) were used in the training set (Supplementary Figure S5). The five variables chosen exhibited no collinearity (Supplementary Figure S6), and the proportional hazards assumption was satisfied (Supplementary Table S1, Supplementary Figure S7).

Prognostic model training and validation

In the multivariate analysis, only pre-chemotherapy (HR: 3.81 [1.72–8.40]; $P < 0.001$), time of obstruction (HR: 0.23 [0.09–0.64]; $p = 0.005$), and post-chemotherapy (HR: 0.16 [0.07–0.36]; $P < 0.001$) were significantly associated with stent patency (Fig. 3B). Three valuable factors were selected to establish the predictive model displayed as a nomogram for individual stent patency prediction at 30-, 90-, 180-, and 360-day (Fig. 3A). To make this predictive model more convenient for physicians to use in clinical scenario, we modified the nomogram into a predictive probability web page calculator, available at https://duyoukansha.shinyapps.io/Stent_Cox_DynNom/. The risk score plots of each patient in the train ing set were showed in Fig. 3C. In the training set, this scoring model exhibited favorable discriminative power, as reflected by the time-dependent AUC of 0.898 (95% CI = 0.760–0.980) at 30-day, 0.778 (95% CI = 0.618–0.917) at 90-day, 0.728 (95% CI = 0.543–0.862) at 180-day, and 0.844 (95% CI = 0.723–0.966) at 360-day (Fig. 4A and D, Supplementary Table S2). In the validation set, this scoring model exhibited moderate discriminative power, as reflected by the time-dependent AUC of 0.654 (95% CI = 0.592–0.716) at 30-day, 0.745 (95% CI = 0.607–0.885) at 90-day, 0.777 (95% CI = 0.582–0.890) at 180-day, and 0.740 (95% CI = 0.586–0.795) at 360-day (Fig. 4E and H, Supplementary Table S2). Moreover, this nomogram also showed moderate calibration in the training and validation sets, as displayed in Fig. 4. The Decision Curve Analysis (DCA) was conducted to evaluate the clinical utility of the predictive nomogram by comparing its net benefit across different threshold probabilities (Fig. 5). The

Table 1 Clinical characteristics of 121 SEMS patients included

Clinical characteristics	Training set (*N* = 85)	Validation set (*N* = 36)	*P* value
Gender, *n* (%)			
Male	64 (75.3%)	21 (58.3%)	0.099
Female	21 (24.7%)	15 (41.7%)	
Age, year, (mean ± SD)	61.1 ± 16.9	61.8 ± 16.9	0.839
Hypertension, *n* (%)			
Yes	21 (24.7%)	7 (19.4%)	0.695
No	64 (75.3%)	29 (80.6%)	
Diabetes, *n* (%)			> 0.999
Yes	8 (9.4%)	3 (8.3%)	
No	77 (90.6%)	33 (91.7%)	
CEA, ng/ml, (Median [IQR])	14.5 [3.8; 131.3]	52.7 [7.7; 604.4]	0.068
WBC, $\times 10^9$/L, (Median [IQR])	7.7 [6.0; 10.0]	7.6 [5.7; 9.5]	0.816
Surgical resection, *n* (%)			0.079
Yes	9 (10.6%)	9 (25%)	
No	76 (89.4%)	27 (75%)	
Site of obstruction, *n* (%)			0.939
Left colon	57 (67.1%)	23 (63.9%)	
Right colon	11 (12.9%)	4 (11.1%)	
Transverse colon	2 (2.4%)	1 (2.8%)	
Rectum	15 (17.6%)	8 (22.2%)	
Stage, *n* (%)			0.242
II	5 (5.9%)	0 (0%)	
III	5 (5.9%)	1 (2.8%)	
IV	75 (88.2%)	35 (97.2%)	
Peritoneal metastasis, *n* (%)			0.168
Yes	41 (48.2%)	23 (63.9%)	
No	44 (51.8%)	13 (36.1%)	
Pre-Chemotherapy, *n* (%)			> 0.999
Yes	37 (43.5%)	16 (44.4%)	
No	48 (56.5%)	20 (55.6%)	
Degree of obstruction, *n* (%)			0.715
Complete	33 (38.8%)	12 (33.3%)	
Incomplete	52 (61.2%)	24 (66.7%)	
Length of obstruction, cm, (Median [IQR])	6.0 [4.0; 6.0]	5.0 [4.0; 6.0]	0.183
Dmax of obstruction, cm, (Median [IQR])	6.0 [5.0; 8.0]	6.0 [5.0; 9.0]	0.741
Time of obstruction, days, (Median [IQR])	9.0 [6.0; 20.0]	7.5 [5.5; 15.0]	0.435
No of stent, *n* (%)			0.730
1	83 (97.6%)	34 (94.4%)	
2	2 (2.4%)	2 (5.6%)	
Length of stent, cm, *n* (%)			0.927
8	9 (10.6%)	3 (8.3%)	
10	57 (67.1%)	25 (69.4&)	
12	19 (22.4%)	8 (22.2%)	
Balloon dilation, *n* (%)			0.049
Yes	8 (9.4%)	9 (25%)	
No	77 (90.6%)	27 (75%)	
Short term complications, *n* (%)			0.771
Absence	68 (80%)	28 (77.8%)	
Obstruction	12 (14.1%)	7 (19.4%)	
Migration	4 (4.7%)	1 (2.8%)	
Other	1 (1.2%)	0 (0%)	
Post chemotherapy, *n* (%)			0.899
Yes	57 (67.1%)	23 (63.9%)	

Table 1 (continued)

Clinical characteristics	Training set (*N* = 85)	Validation set (*N* = 36)	*P* value
No	28 (32.9%)	13 (36.1%)	
Stent expansion rate at day 1, %, (mean ± SD)	45.2 ± 15.0	45.4 ± 13.9	0.930
Clinical success, *n* (%)			
Yes	81 (95.3%)	34 (94.4%)	> 0.999
No	4 (4.7%)	2 (5.6%)	
Stent Patency, *n* (%)			> 0.999
No	39 (45.9%)	16 (44.4%)	> 0.999
Yes	46 (54.1%)	20 (55.6%)	
Patency time, days, (Median [IQR])	120.0 [58.0; 217.0]	108.0 [31.0; 187.5]	0.264

[a] Continuous variables were presented as mean ± SD for normal distribution or median (IQR) for non-normal distribution and categorical variables as Number (%).
[b] *p* values were calculated using the Student's *t*-test for normally distributed or Wilcoxon Signed Rank test for non-normally distributed continuous variables and the χ^2 test for categorical variables.
SD = standard deviation, IQR = interquartile range

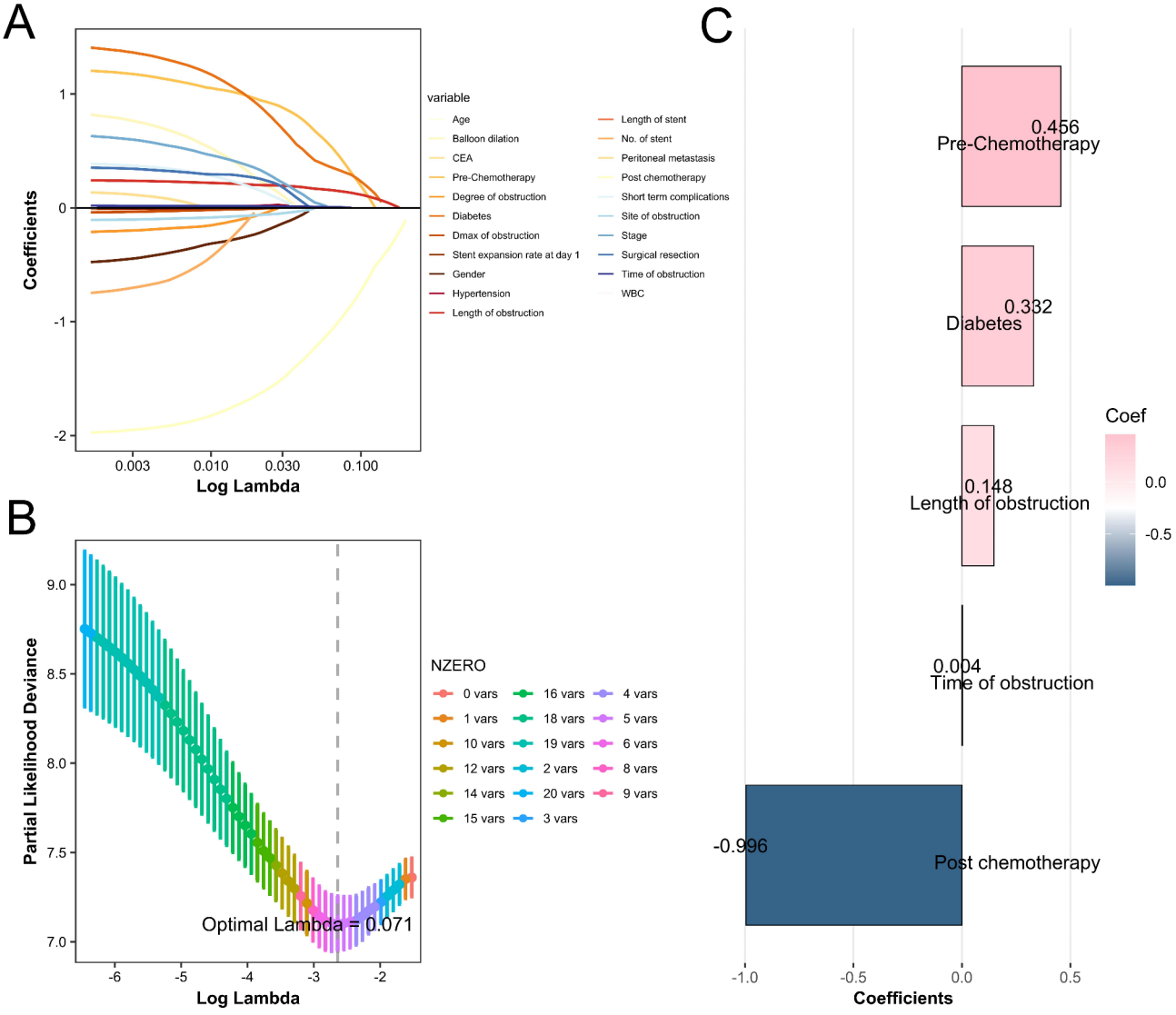

Fig. 2 (**A**) LASSO coefficient profiles of the 21 candidate risk factors in the training set. (**B**) Five risk factors selected using LASSO Cox regression analysis. The grey dotted vertical line was drawn at the optimal score by minimum criteria. (**C**) The corresponding coefficient bar plot of selected five variable

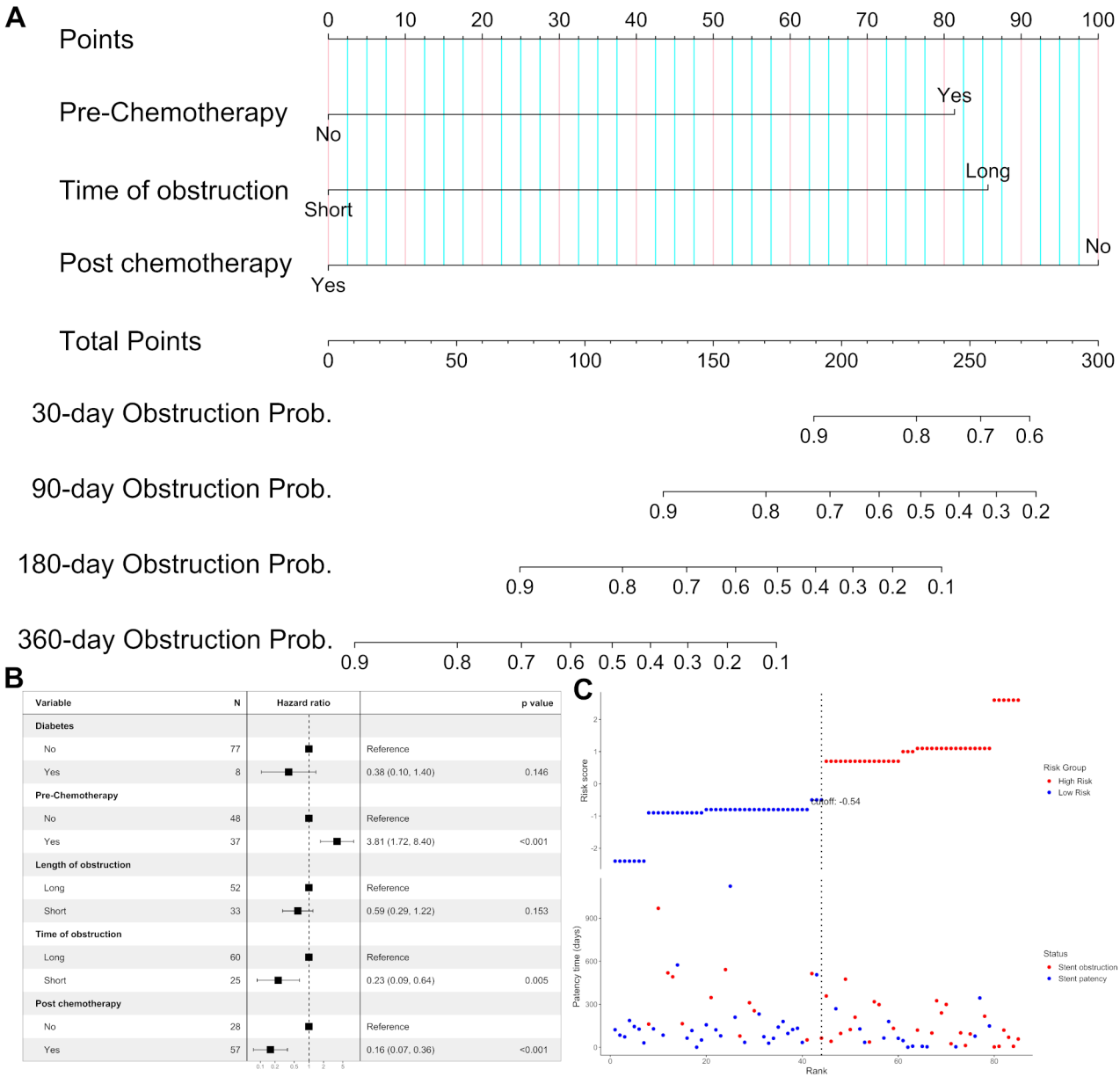

Fig. 3 (**A**) Nomogram of the current model for individual stent patency prediction at 30-, 90-, 180-, and 360-day, and its corresponding web version was available athttps://duyoukansha.shinyapps.io/Stent_Cox_DynNom/. (**B**) The forest plot based on the multivariable Cox regression model with the candidate five categorical variables. (**C**) The risk score plot of all patients in the training set in ascending order and marked as low risk (blue) or high risk (red), as divided by optimal value − 0.54 (vertical dashed line) in the upper part. Following up and stent patency status of each patient, and stent patency or stent obstruction patient is marked as blue or red, respectively in the bottom part

threshold probability defines the risk level at which a clinician might consider intervention based on the model's prediction. The training set exhibited a threshold probability range of 8–96% (Fig. 5A), and the validation set demonstrated a threshold probability range of 13–92% (Fig. 5B). These results indicate that for patients with an estimated risk falling within this range, the predictive nomogram provides a higher net benefit compared to treating all patients indiscriminately or withholding treatment entirely. The wide range of beneficial thresholds supports the practical applicability and generalizability of the model in clinical decision-making, ensuring a balanced approach between overtreatment and undertreatment risks. Furthermore, contour plots illustrating the effects of the three key predictive variables (pre-chemotherapy, time of obstruction, and post-chemotherapy) on stent patency probability in the training set are provided in Supplementary Figure S8. These plots

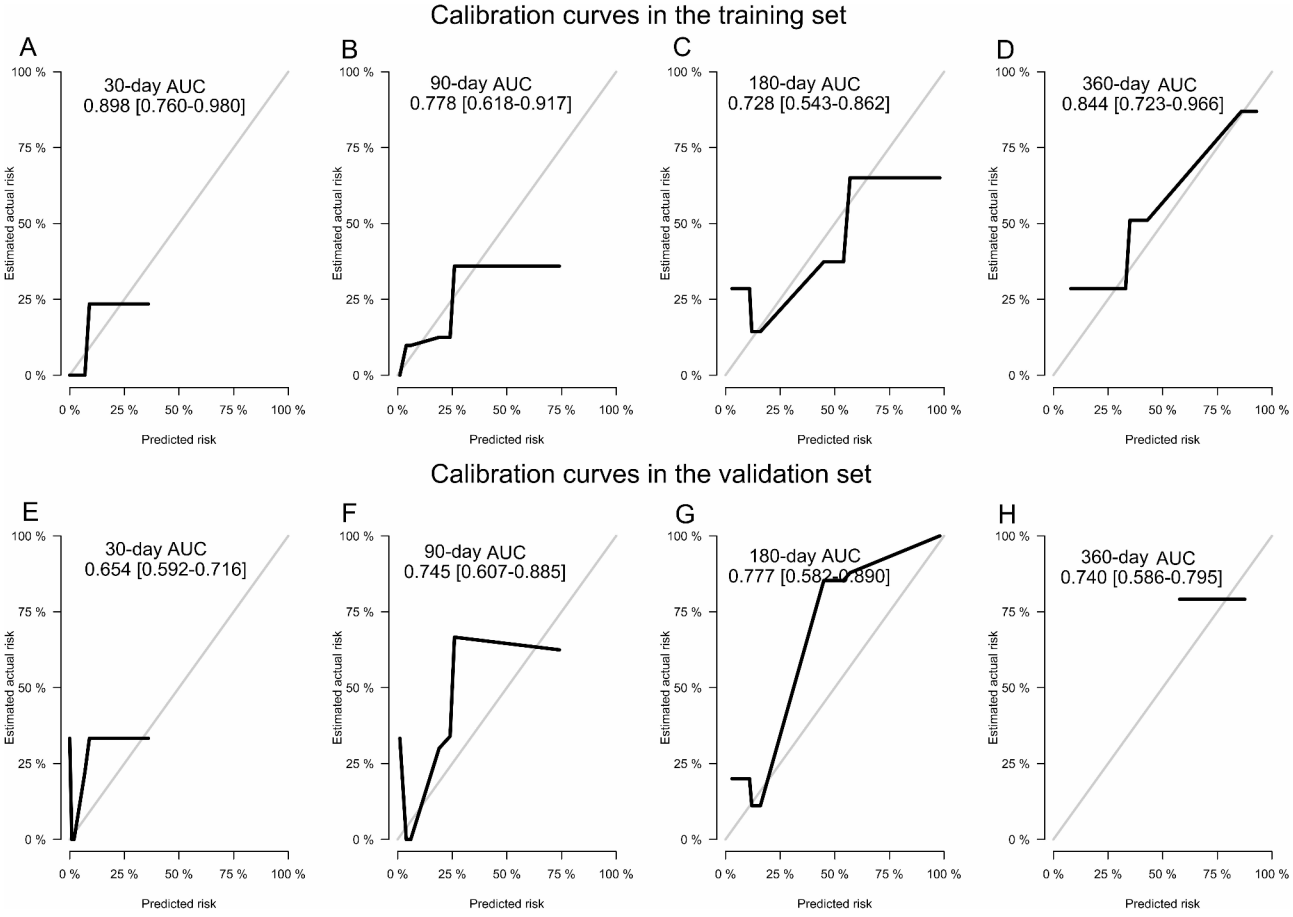

Fig. 4 Calibration curves and time-dependent AUC values of the final predictive model. (**A**–**D**) Calibration curves and corresponding AUC values at 30, 90, 180, and 360 days in the training set. (**E**–**H**) Calibration curves and corresponding AUC values at 30, 90, 180, and 360 days in the validation set

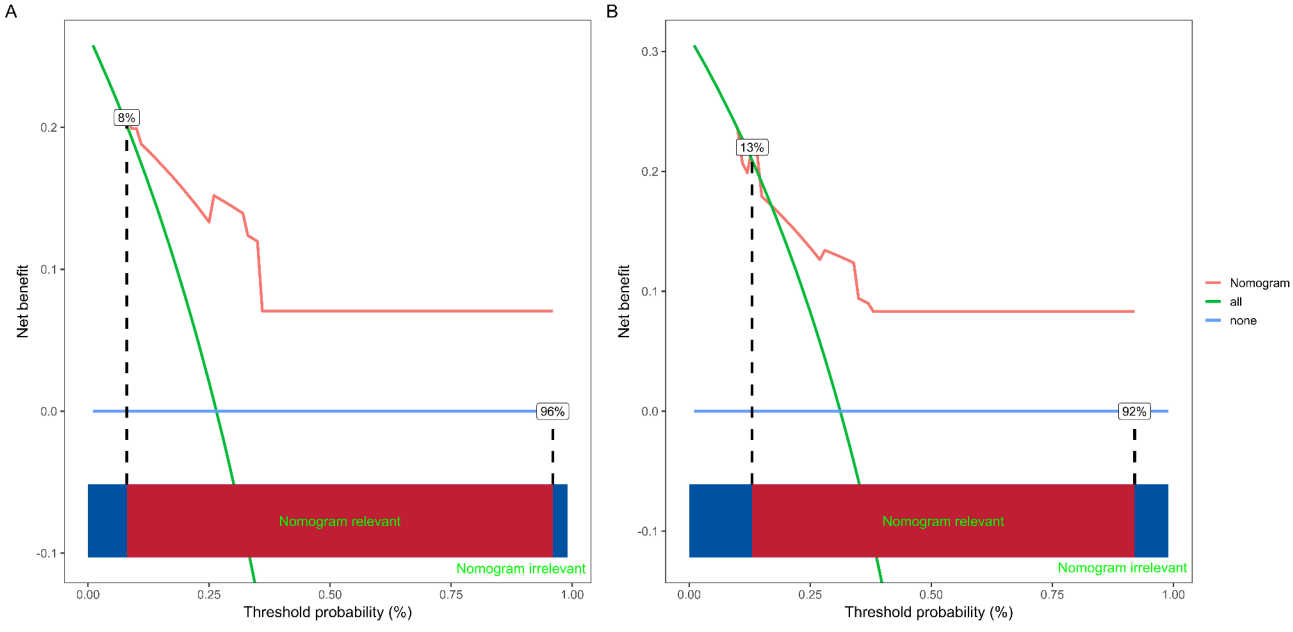

Fig. 5 Decision curve analysis (DCA) for model utility evaluation, illustrating the net benefit of using the predictive nomogram for clinical decision-making across different threshold probabilities. (**A**) DCA results for the training set, with threshold probabilities ranging from 8–96%. (**B**) DCA results for the validation set, with threshold probabilities ranging from 13–92%

visually depict the relationship between each variable and the probability of maintaining stent patency over time, enhancing interpretability and clinical insight into the model's predictive capabilities.

To further investigate the impact of chemotherapy regimens on stent patency, we conducted stratified Cox regression analyses for the most frequently used regimen in both the pre-chemotherapy and post-chemotherapy groups, namely FOLFOX. The results of these analyses are visually represented using nomograms (Supplementary Figure S9), integrating key prognostic factors to provide individualized risk predictions for stent patency within these subgroups.

Discussion

Self-expanding metal stents (SEMS) is commonly advised as the initial palliative intervention for malignant colonic obstruction [1], and given the critical importance of long-term stent patency for patient survival, numerous studies have identified factors that affect long-term stent patency [3, 5, 17]. Regrettably, no accurate or specific methodology for predicting stent patency after palliative SEMS is publicly available in clinical settings.

In recent years, the advancement of analytical methodologies has facilitated the application of mathematical models incorporating multiple markers within the medical field [18, 19]. This methodology integrates a series of significant parameters to develop a predictive model, thereby enhancing diagnostic performance. In the current study, clinical, laboratory, and operative characteristics were selected through multivariate regression analysis to construct a predictive model, which incorporated the therapeutic variables (pre- and post-chemotherapy) and time of obstruction. To establish an innovative scoring system, the nomogram was converted into a scoring system. The scoring system developed in this study demonstrated robust diagnostic performance in both the training and validation datasets. Additionally, we conducted an analysis of the model's predictions across various time points and determined that it exhibits robust diagnostic capabilities in its predictive performance at these distinct intervals (Fig. 4).

Prior research found that stent patency time was not improved by combining with palliative chemotherapy [5, 20, 21], unlike the findings of our study. Our analysis posits several potential explanations for this disparity. Firstly, one key contributing factor to stent restenosis is tumor regrowth within the stent [5, 22], while advancements in chemotherapy protocols for primary colorectal cancer have resulted in improved tumor response rates and extended survival durations [23], ultimately leading to increased stent patency. Secondly, prior research often combined patients with primary and secondary malignant colorectal obstructions in their analyses [3, 5, 17]. Nevertheless, the lower clinical success rate and higher complications rate in patients with secondary malignant colorectal obstructions were already revealed [24], which could cause a certain bias. However, in the above-mentioned studies lack clarity in distinguishing between pre- and post-SEMS chemotherapy. In the clinical setting, patients may exhibit initial obstruction or encounter re-obstruction while undergoing chemotherapy, which can result in diverse reactions to tumor response. This study compared two different time points of chemotherapy and observed contrasting effects on stent patency, potentially attributable to the heightened tumor response rate and extended survival period of patients who received the initial chemotherapy. Besides, a recent review [25] found no increased risk of complications or decreased survival with chemotherapy in relation to SEMS, and no strong evidence of antiangiogenic agents causing stent perforation. Similarly, there also was no significant difference comparison with chemotherapy or not in this study (Supplementary Table S3, $P = 0.373$).

The findings of this study indicate a correlation between obstruction duration and long-term stent patency, a relationship not previously documented in existing literature. The guidelines established by the European Society of Gastrointestinal Endoscopy (ESGE) recommend [4] prompt removal of obstructions in emergency cases, even in the absence of pathological evidence, although a precise timeframe for intervention is not specified. The findings of this study indicate that early stent release within 6 days of symptom onset may enhance long-term stent patency. This improvement is likely attributed to prompt obstruction removal, facilitating enteral nutrition and enhancing patient physical well-being. Additionally, expedited chemotherapy administration may contribute to enhanced long-term survival rates. Nevertheless, it is not recommended to universally endorse early SEMS as superior for all patients, and stent implantation should be avoided for patients lacking clear obstructive symptoms [4]. Consequently, when considering stenting procedures, it is imperative to evaluate not only the duration of obstruction but also the necessity of stenting for each individual patient.

In the palliative stent treatment for malignant colon obstruction, factors such as stent expansion rate and peritoneal metastasis [3, 5] have been identified as common contributors to stent occlusion. Suh JP et al. [5] revealed that stents with less than 70% dilation within 48 h post-implantation exhibit shorter patency durations. Additionally, patients demonstrating over 90% dilation on the first day after stent placement are at a heightened risk of stent displacement, leading to a reduced duration of reintervention-free survival [3]. However, in this study, we did not find any significant association between stent expansion rates on the first day after SEMS

and long-term stent patency. This discrepancy can be ascribed to multiple factors. Firstly, earlier research [3, 5, 6] predominantly utilized abdominal digital radiography instead of computed tomography (CT) to assess stent expansion rates. Radiography, however, produces two-dimensional projection images, which may result in measurement inaccuracies, particularly in instances of asymmetric stent expansion or when X-rays are taken at oblique angles. Secondly, the absence of comprehensive methodological descriptions in prior literature concerning measurement protocols introduces potential variability and error in data collection.

Peritoneal metastasis is frequently regarded as a risk factor associated with diminished technical and clinical efficacy. Patients with peritoneal metastases exhibited decreased stent reintervention-free survival [3], resulting in shorter stent patency durations, but secondary obstruction accounted for a large proportion of patients in the study (37.1%). In another study [26] that stratified peritoneal metastases into categories of mild, moderate, and severe, it was determined that the prevalence of severe peritoneal cancer was significantly greater in the extracolonic malignancy cohort compared to the colorectal cancer cohort (87.6% vs. 12.9%; $P<0.001$). Additionally, patients with severe cancer were less likely to receive anticancer therapy ($P=0.03$). Hence, we posit that the elevated incidence of peritoneal metastasis in individuals with secondary malignant obstruction, coupled with the lack of post-stenting chemotherapy for a variety of reasons, typically results in a shorter duration of stenting. Conversely, this phenomenon is less common in cases of primary colon obstruction, with a higher proportion of patients in this study receiving subsequent chemotherapy (67.1% in the training set and 63.9% in the Validation set, as shown in Table 1).

The role of external validation in model development continues to be a subject of debate. Certain studies advocate for its inclusion during the development phase, suggesting that it enhances model accuracy, which is crucial as clinical decisions based on inaccurate predictive models can negatively impact patient outcomes [27]. Conversely, recent guidelines and consensus statements assert that external validation should be reserved for a subsequent phase, conducted independently by researchers not involved in the initial model development [19, 28]. In our own model development and validation process, external validation was not incorporated, indicating that the clinical accuracy of the model requires further assessment. Consequently, this study introduces a web-based calculator (available at [https://duyoukansha.shinyapps.io/Stent_Cox_DynNom/]) designed to facilitate multi-center application and to support future external validation efforts.

First, the retrospective design may introduce selection bias. Although systematic variable selection was performed using LASSO and Cox regression, tumor burden parameters (e.g., stage, obstruction severity, peritoneal metastases) were not retained as independent predictors, implying limited prognostic weight in our model. Second, the small validation cohort ($N=36$) likely contributed to population differences (compared to training set, such as balloon dilatation, $P=0.049$), reduced generalizability and overfitting (evidenced by AUC discrepancies). To address these limitations and further clarify model generalizability, rigorous external validation in a larger, multi-center cohort is imperative to confirm robustness and mitigate overfitting risks. Third, while stratified analysis confirmed chemotherapy timing and FOLFOX regimen impacts stent patency (Supplementary Figure S9), regimen-specific effects require confirmation in larger cohorts. Finally, although our SEMS placements were radiologically guided, existing evidence shows comparable outcomes with endoscopic methods [4]. Future priorities include: (1) external validation with multi-center datasets; (2) stratified analyses of tumor burden and comorbidities; (3) regimen-specific chemotherapy evaluations.

Conclusion

The nomogram demonstrated high accuracy and robustness in predicting stent patency during development and internal validation, offering a practical tool for personalized SEMS management. However, rigorous external validation in larger, multi-center cohorts is mandatory to confirm its generalizability before clinical implementation.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12957-025-03782-6.

Supplementary Material 1

Acknowledgements

Supported by the Medical Joint Fund of Jinan University (YXZY2024020) and the program of Guangdong Provincial Clinical Research Center for Digestive Diseases (2020B1111170004).

Author contributions

1.Yuan wan: Conceptualization (lead), Data Curation (lead), Methodology (lead), Validation (equal), Writing - Original Draft (lead), Writing - Review & Editing (lead). 2.Meng-sha Zou: Data Curation (equal), Methodology (lead), Validation (equal), Writing - Original Draft (equal), Writing - Review & Editing (equal). 3.Zhao-fei Zeng: Data Curation (lead), Methodology (equal), Validation (equal). 4.Xiao-zheng Cao: Writing - Original Draft (supporting), Writing - Review & Editing (supporting). 5.Huan-hua Wu: Conceptualization (lead), Data Curation (supporting), Methodology (lead), Validation (lead), Writing - Original Draft (equal). 6.Bo Zhang: Resources (lead), Conceptualization (supporting), Methodology (supporting), Writing - Original Draft (lead), Writing - Review & Editing (lead). All authors reviewed the manuscript.

Funding
No funding was received for this work.

Data availability
Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate
This study was approved by the ethics committee of The Sixth Affiliated Hospital, Sun Yat-sen University, Guangzhou, China.

Consent for publication
Written informed consent was obtained from all individual participants included in the study.

Competing interests
The authors declare no competing interests.

Received: 13 February 2025 / Accepted: 26 March 2025
Published online: 11 April 2025

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