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RESEARCH

Combination of radiomic and clinical characteristics to predict mortality in patients with colorectal perforation

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Abstract

Purpose We aim to construct and verify a model combining radiomic and clinical data to predict early mortality in patients with colorectal perforation in a two-center study.

Methods Data from 147 patients at Xiaogan Central Hospital (2014–2024) and 52 patients at Southern Hospital of Southern Medical University (2021–2023) were collected for model training and validation. Univariate and multivariate analyses were performed to identify risk factors associated with mortality. Radiomic characteristics from CT scans were extracted via least absolute shrinkage and selection operator (LASSO) regression to construct an imaging score. A nomogram was developed by integrating the findings from the multivariate analysis. Predictive performance was evaluated via the area under the receiver operating characteristic curve (AUC), and clinical utility was assessed via decision curve analysis (DCA).

Results Univariate analysis highlighted age, ASA classification, shock index, rad-score, white blood cell (WBC) count, neutrophil (N) and lymphocyte (L) counts, sodium (Na^+), creatinine (Cr), and procalcitonin (PCT) as significant prognostic indicators for mortality ($p < 0.05$). Multivariate analysis confirmed age, ASA classification, PCT, and rad-score as independent prognostic factors. The radiomic combined with clinical characteristics nomogram (RCCCN) includes four variables: the patient's age, ASA classification, PCT level, and rad-score. The RCCCN model demonstrated excellent predictive performance for mortality risk in the validation cohort (AUC: 0.92, 95% CI: 0.84–0.99) with good calibration.

Conclusion A nomogram combining radiomic features and clinical characteristics effectively predicts mortality in patients with colorectal perforation, providing a valuable tool for clinical decision-making and patient management.

Keywords Radiomics · Colorectal perforation · Prognostic factors · Predictive model · CT imaging

Introduction

Colorectal perforation is a serious condition associated with high morbidity and mortality rates. The global incidence of colorectal perforation varies, with some estimates suggesting that it accounts for up to 20% of all colorectal surgeries, underscoring its clinical significance in gastrointestinal emergencies [[1–3]]. Despite advancements in surgical procedures and postoperative care, the risk of mortality due to colorectal perforation remains significantly high, ranging from 6 to 33%, depending on the study and patient cohort [[4–8]]. The causes of death in these patients often include sepsis-induced shock, disseminated intravascular coagulopathy, and multiple organ dysfunction syndrome [[9]]. Immediate surgical intervention remains the standard treatment for colorectal perforation, with careful preoperative assessment required to determine condition severity and pinpoint potential mortality risk factors [[10]]. Various risk factors

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have been identified, including age, body mass index (BMI), serum protein levels, etiology of perforation, coagulopathy, and serum creatinine levels [[11–16]]. However, integrating these factors into a predictive model capable of accurately stratifying patients the basis of on their risk remains a challenge [[17]]. In recent years, interest in the use of radiomic features—quantitative imaging phenotypes derived from medical images—to complement clinical data in predicting patient outcomes has increased [[18]]. Studies have demonstrated that radiomic models can offer robust predictive capabilities and hold significant potential for clinical application [[19–21]].

We aim to identify the elements that affect the prognosis in patients with colorectal perforation who are undergoing surgical intervention and to devise a prognostic tool that integrates radiomic features and clinical profiles for predicting mortality in patients. The clinical application value of prognostic models in predicting outcomes for patients with colorectal perforation, and to evaluate the clinical application value of the model in predicting the prognosis of patients with colorectal perforation.

Materials and methods

Patients

We gathered patient data from two medical centers regarding colorectal perforation diagnoses: 147 cases from Xiaogan Central Hospital (XGCH) from January 2014 to August 2024, and 52 cases from the Southern Hospital of Southern Medical University (SHSMU) from January 2021 to December 2023. Our inclusion criteria were patients with colorectal perforation who presented signs of perforation on preoperative CT images and were confirmed during the operation. The criteria for exclusion were as follows: (1) patients with colorectal perforation who had not undergone surgical treatment; (2) patients who died during the perioperative period or due to cardiovascular and cerebrovascular accidents; and (3) patients whose clinical data were missing. A total of 26 patients were excluded based on the predefined exclusion criteria. Specifically, 22 patients did not undergo surgical treatment, 2 patients died during the perioperative period due to cardiovascular and cerebrovascular accidents, and 2 patients had missing data due to the long duration since their treatment. This detailed exclusion process ensured the consistency and accuracy of our study cohort, leaving 173 patients included in the study. Participants were randomly allocated into two groups: a training cohort (n = 104) and a validation cohort (n = 69), following a 6:4 distribution. The main outcome of the study was 30-day postoperative mortality. Based on their 30-day postoperative outcomes, individuals in the training cohort were split into a survival group (n = 80) and a mortality group (n = 24), and factors associated with death were analyzed. Thirty-day postoperative mortality was defined as death from any cause occurring during the hospital stay or within 30 days following surgery. Figure 1 illustrates the patient selection process in a flowchart.

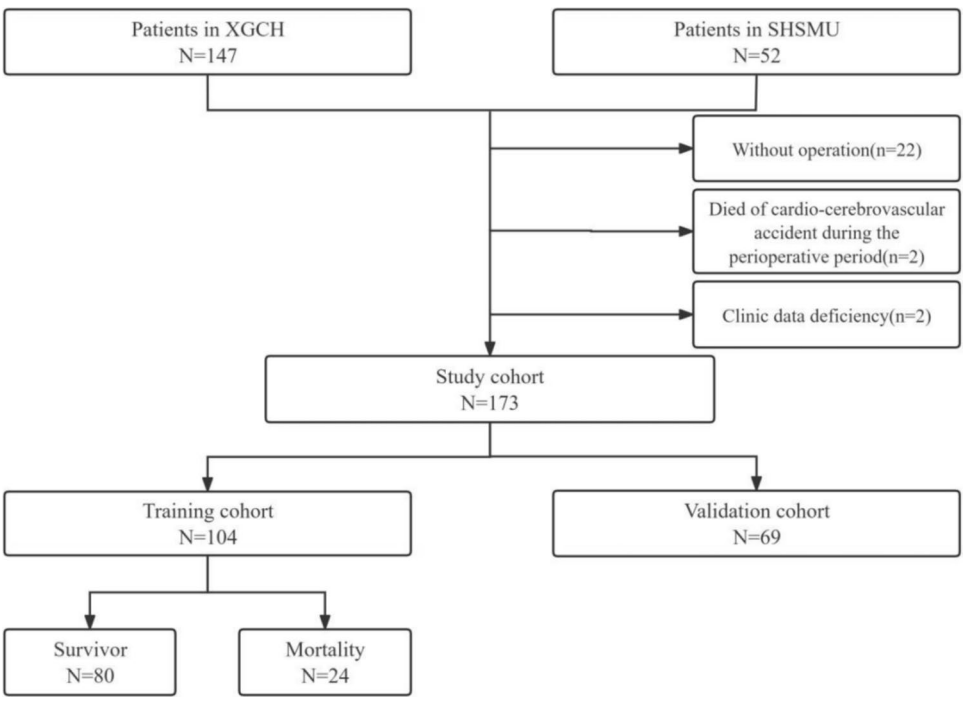

Fig. 1 Patient selection

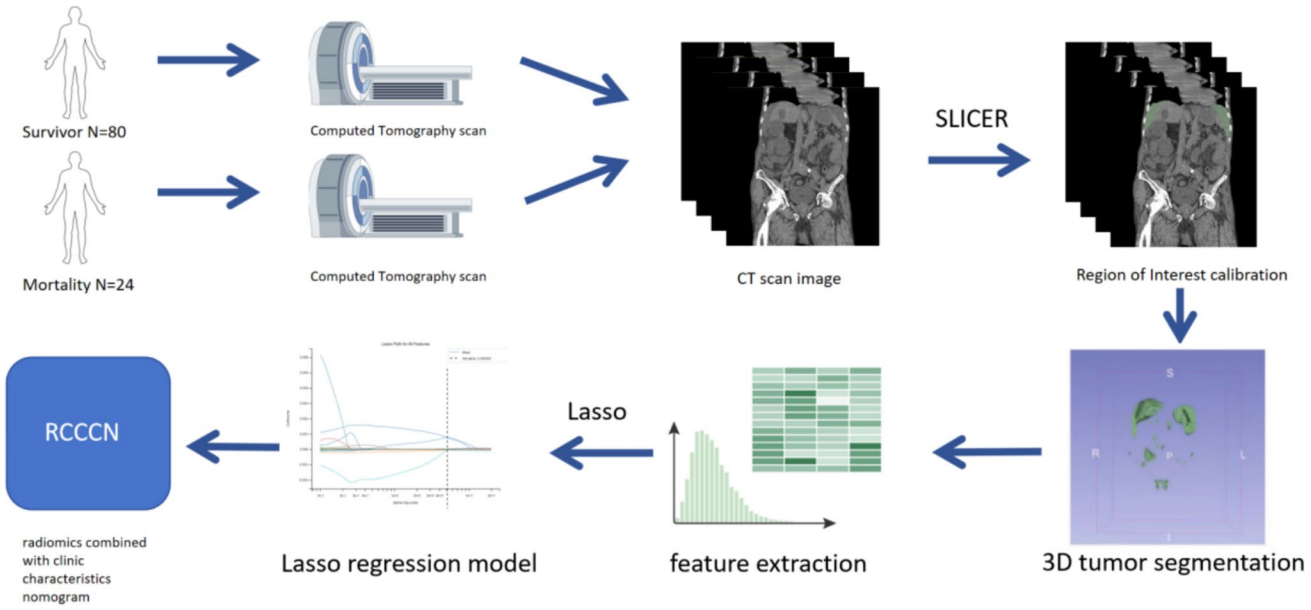

Fig. 2 Flowchart of CT image acquisition and model construction

Collected data

The patient data were collected through a retrospective chart review of electronic medical records from the two participating hospitals. The baseline patient data collected included age, sex, initial vital signs, and duration of illness. The surgery-related information included ASA classification, perforation details (location, size, cause, and type), operation time, postoperative complications, and postoperative pathology. Preoperative clinical parameters include white blood cell (WBC) count, hemoglobin (Hb), neutrophil count (N), lymphocyte count (L), electrolytes, total bilirubin (TBil), albumin (ALB), amylase, creatinine (Cr), C-reactive protein (CRP), and procalcitonin (PCT).

CT image acquisition and feature extraction

Preoperative multidetector spiral CT (MDCT) was performed in all patients, scanning from the diaphragmatic dome to the pubic symphysis. The image reconstruction parameters included a slice thickness of 2.5 mm and a standard reconstruction algorithm. The images were evaluated by two radiologists for the presence of colonic or rectal perforation and ascites. CT image acquisition was performed on different CT scanners. The CT images were then subjected to three-dimensional reconstruction of ascites using the SLICER software (version 5.6.2) [[22,23]], further analysis and processing of the features were performed using the `pyradiomics` library in Python (version 3.9.10). Since the software cannot automatically detect ascites, manual segmentation of the ascites region was performed by two experienced radiologists using 3D Slicer software. The processing steps and feature extraction process are shown in Fig. 2. Features were selected using LASSO (version 3.12), and a rad-score was constructed by adjusting the regularization parameter (λ).

To evaluate the reproducibility of feature extraction by the two radiologists, we calculated the correlation coefficients for all extracted features using Python (version 3.12). The results showed that all correlation coefficients (0.997) were greater than 0.80, indicating high reproducibility in the feature extraction process. This supports the reliability of our radiomic features.

Radiomic score

19 features were obtained via Lasso, with details available in the supply.

$$\text{Rad-score} = \beta0 + \beta1 \cdot \text{Mean} + \beta2 \cdot \text{Minimum} + \beta3 \cdot \text{Maximum} + \beta4 \cdot \text{MeshVolume} + \beta5 \cdot \text{SurfaceArea} + \beta6 \cdot \text{VoxelVolume} + \beta7 \cdot \text{Minimum.1} + \beta8 \cdot \text{Range} + \beta9 \cdot \text{Energy} + \beta10 \cdot \text{ClusterProminence} + \beta11 \cdot \text{ClusterShade} + \beta12 \cdot \text{Variance} + \beta13 \cdot \text{GrayLevelNonUniformity} + \beta14 \cdot \text{GrayLevelNonUniformity.1} + \beta15 \cdot \text{RunLengthNonUniformity} + \beta16 \cdot \text{LargeAreaEmphasis} + \beta17 \cdot \text{LargeAreaHighGrayLevelEmphasis} + \beta18 \cdot \text{ZoneVariance} + \beta19 \cdot \text{Complexity}.$$

The rad-score for each patient was calculated via this formula within the cohort.

Statistical analysis

For missing data values, we used the median imputation method, replacing missing values with the median of the variable. For variables with half or more of the values missing, such as blood type, we deleted the entire series of values in subsequent analyses. Continuous variables are expressed as the means and standard deviations in parentheses, whereas categorical variables are represented by absolute numbers and percentages. For comparisons between groups of normally distributed metric data, the two-independent samples t-test was used; for nonnormally distributed metric data, nonparametric tests were applied; and for comparisons between groups of count data, the chi-square test was utilized. The risk factors associated with mortality in colorectal perforation were identified based on univariate analysis, and multivariate logistic regression analysis was employed to pinpoint the independent risk factors that contribute to mortality in patients undergoing treatment for colorectal perforation. Using LASSO regression, a tuning parameter λ is introduced, which forces some unimportant coefficients to zero, thereby automatically selecting important features. A nomogram was plotted to develop a forecasting model, and the data from the validation cohort were evaluated via the area under the receiver operating characteristic (ROC) curve (AUC) to assess the model's predictive accuracy. Goodness-of-fit tests assess the overall fit of the model, while clinical net benefit evaluations assess its clinical effectiveness. This study followed the TRIPOD reporting guidelines. All statistical analyses were conducted using SPSS (version 26.0).

Results

The research involved a sample of 173 patients, categorized into two distinct cohorts. An analysis of the demographic and clinical characteristics across these cohorts showed no significant differences in terms of age, onset time, sex, ASA classification, or perforation site ($P > 0.05$). Postoperative death rates were nearly identical between the training cohort (23.08%) and the validation cohort (23.19%). Table 1 summarizes the demographic and clinical characteristics of the two cohorts.

The study of perforation sites and causes in patients revealed that left-sided perforations were the most common, accounting for 79.81% of cases, with sigmoid colon perforations being the most common at 58.65%, followed by rectal perforations at 15.38%. Perforation etiologies can be broadly classified into two primary types: traumatic and nontraumatic. Traumatic perforations often result from external injuries, intra-abdominal foreign bodies rupturing the intestinal wall, and iatrogenic injuries (such as endoscopic procedures, stent placements, and gastrointestinal contrast studies). Nontraumatic perforations are more commonly associated with colorectal tumor perforations, diverticula, fecalith obstruction perforations, inflammatory bowel disease perforations such as ulcerative colitis, Crohn's disease, localized ischemic necrosis perforations, and those caused by parasites. In our study, inflammation (42 cases, 40.38%) and tumors (24 cases, 23.08%) were the most common causes. Inflammatory perforation had a mortality rate of 26.19%, whereas tumor-related perforation had a rate of 29.17%, with no significant difference in mortality among different causes. Table 2 details the distribution of perforation sites, causes, and associated mortality in the training cohort.

Table 1 Demographic and clinical data comparison in two cohorts

	Total (N = 173)	Training cohort (N = 104)	Validation cohort (N = 69)	P
Age, years	66.75 ± 14.81	66.19 ± 16.22	67.61 ± 12.49	0.635
Time of onset, hours	65.36 ± 90.14	66.81 ± 91.08	63.12 ± 89.76	0.710
Sex, n(%)				
Male	93 (53.76)	56 (53.85)	37 (53.62)	0.403
Female	80 (46.24)	48 (46.15)	32 (46.38)	
ASA classification, n(%)				
≥ 3 grade	77 (44.51)	44 (42.31)	33 (47.83)	0.727
< 3 grade	96 (55.49)	60(57.69)	36 (52.17)	
Perforation site, n(%)				
Left	138 (79.77)	83(79.81)	55 (79.71)	0.101
Right	35 (20.23)	21(20.19)	14(20.29)	
Mortality, n(%)	40 (23.12)	24(23.08)	16 (23.19)	0.798

Data are presented as means ± standard deviations or as n (%).

Table 2 Perforation site, cause, and mortality comparison in the training cohort

	Total (N = 104)	Mortality (N = 24)	Survivor (N = 80)	P
Perforation site, n(%)				
Left	83 (79.81)	21 (87.50)	62 (77.50)	0.435
Right	21 (20.19)	3 (12.50)	18 (22.50)	
Perforated intestinal Segment,n(%)				
Sigmoid	61 (58.65)	15 (62.50)	46 (57.50)	0.663
Rectum	16 (15.38)	5 (20.83)	11 (13.75)	
Ascending colon	9 (8.65)	1 (4.17)	8 (10.00)	
Descending colon	6 (5.77)	1 (4.17)	5 (6.25)	
Transverse colon	6 (5.77)	1 (4.17)	5 (6.25)	
Cecum	6 (5.77)	1 (4.17)	5 (6.25)	
Perforation cause, n(%)				
Inflammation	42 (40.38)	11 (45.83)	31 (38.75)	0.975
Tumor	24 (23.08)	7 (29.17)	17 (21.25)	
Diverticulitis	11 (10.58)	2 (8.33)	9 (11.25)	
Unknown	12 (11.54)	4 (16.67)	8 (10.00)	
Iatrogenic injury	6(5.77)	0 (0.00)	6(7.50)	
Foreign body	4 (3.85)	0 (0.00)	4 (5.00)	
Mortality, n(%)				
Inflammation	42	11(26.19)		
Tumor	24	7 (29.17)		

Data are presented as n (%).

This study examined the preoperative clinical data and postoperative mortality rates of patients in the training cohort, with 24 deaths and a postoperative mortality rate of 23.08%. The median age within the patient cohort was 66.19 ± 16.22 years. Additionally, the mean age of the mortality group (75.79 ± 10.06) was significantly greater than that of the survivor group (64.04 ± 14.98). The mortality rate for perforations in the left colon (from the descending colon to the rectum) was 87.5%, which was higher than that for those in the right colon (from the ileocecal junction to the transverse colon) at 12.5%, however, the difference lacked statistical significance. Additionally, no correlation existed between sex, time of onset, operation time, perforation disease, type of perforation, or mortality rate ($P > 0.05$), whereas age, ASA classification, shock index (SI), and preoperative CT radiomics scores were statistically significant ($P < 0.05$), as shown in Table 3.

When comparing the laboratory data between the mortality and survivor groups, we observed no statistically significant differences in the mortality rates for serum albumin, CI^-, TBil, or CRP (Table 4). The WBC count, N count, L count, Na^+, creatinine, and PCT were correlated with mortality ($P < 0.05$). The cutoff values revealed that a patient age of ≥ 75 years, ASA classification of ≥ 3, WBC count of ≥ 4.52, neutrophil count of ≥ 6.33, and lymphocyte count of ≥ 0.55 were significantly associated with mortality.

In the univariate analysis, we identified ten statistically significant indicators, which were then included in the multivariate logistic regression analysis. Table 5 shows the results of the analysis, where age ≥ 75 years (OR = 10.27, 95% CI: 1.02–103.02), ASA classification ≥ 3 (OR = 15.96, 95% CI: 1.11–229.63), PCT (OR = 1.02, 95% CI: 1.01–1.04), and Rad-score (OR = 5.93, 95% CI: 1.01–34.85) were risk factors for mortality in patients with colorectal perforation (all P values < 0.05).

A nomogram (Fig. 3) was constructed on the basis of four factors, namely, age ≥ 75 years, ASA classification ≥ 3, PCT level, and Rad-score, to estimate the likelihood of mortality in patients with colorectal perforation. We selected two cases of perforation patients from Xiaogan Central Hospital in 2024 between November and December (samples out of this study), a patient with colorectal perforation, aged 62 years, with an ASA classification of 3 and a PCT value of 0.17, and a rad-score of 0, corresponding to a total score of 112.5 on the nomogram, which corresponds to a death risk probability of less than 0.1 for the patient. This patient was discharged 10 days after the operation. Another patient, aged 85 years, had an ASA classification of 3, a PCT value of 50, and a rad-score of 2.4. These factors corresponded to a total score of 214.4 on the nomogram, which corresponds to an approximate death risk probability of 0.8 for the patient. The patient died two days after the operation.

Table 3 Comparison of preoperative clinical indicators between survival and mortality in the colorectal perforation training cohort

	Survivor (N = 80)	Mortality (N = 24)	P
Gender			
Male	42	14	0.616
Female	38	10	
Age, years			
≥ 75	12	20	**< 0.001***
< 75	68	4	
ASA classification			
≥ 3 Grade	21	23	**< 0.001***
< 3 Grade	59	1	
Location			
Left	62	21	0.292
Right	18	3	
Disease			
Malignant	63	17	0.059
Benign	17	7	
Type of perforation			
Free intraperitoneal	48	14	0.247
In the mesentery	32	10	
Time of onset, hours	75.24 ± 96.33	32.42 ± 55.20	0.061
Operation time, hours	3.06 ± 1.10	3.18 ± 0.94	0.629
Shock index	0.80 ± 0.25	0.98 ± 0.45	**0.021***
Rad-score	0.28 ± 2.51	2.07 ± 2.04	**< 0.001***

Data are presented as n, or the mean ± standard deviation, *p < 0.05.

Table 4 Univariate analysis of laboratory test results for 104 patients in the training cohort

	Survivor (N = 80)	Mortality (N = 24)	OR (95% CI)	P
WBC	61	8	0.17 (0.06 ~ 0.45)	**< 0.001***
N	46	5	0.19 (0.07 ~ 0.57)	**0.003***
L	51	3	0.08 (0.02 ~ 0.29)	**< 0.001***
ALB	18	5	0.94 (0.31 ~ 2.89)	0.916
Na^+	139.51 ± 3.99	142.09 ± 4.14	1.18 (1.04 ~ 1.35)	**0.012***
Cl^-	102.59 ± 5.04	104.50 ± 4.47	1.08 (0.98 ~ 1.20)	0.120
TBil	16.19 ± 10.71	21.80 ± 14.43	1.04 (1.00 ~ 1.08)	0.056
Cr	97.94 ± 56.25	134.21 ± 71.21	1.01 (1.01 ~ 1.02)	**0.001***
CRP	116.31 ± 107.55	104.47 ± 106.63	1.00 (0.99 ~ 1.00)	0.633
PCT	10.98 ± 27.94	65.78 ± 74.94	1.02 (1.01 ~ 1.04)	**0.010***

WBC white blood cell count, N neutrophil count, L lymphocyte count, ALB albumin, TBil total bilirubin, Cr creatinine, CRP C-reactive protein, PCT procalcitonin, OR odds ratio; *p < 0.05.

Table 5 A multivariate logistic regression model was utilized to evaluate the risk factors associated with mortality in individuals suffering from colorectal perforation

	OR	95% CI	*P*
Age	10.27	1.02 ~ 103.02	**0.031***
ASA	15.96	1.11 ~ 229.63	**0.042***
WBC	1.13	0.08 ~ 16.22	0.927
N	0.27	0.01 ~ 5.51	0.393
L	0.75	0.09 ~ 6.07	0.789
SI	0.16	0.00 ~ 6.98	0.344
Na^+	1.13	0.88 ~ 1.46	0.337
Cr	1.01	0.99 ~ 1.02	0.389
PCT	1.02	1.01 ~ 1.04	**0.044***
Rad-score	5.93	1.01 ~ 34.85	**0.039***

* p < 0.05

The effectiveness of the RCCCN model in making predictions was evaluated via the receiver operating characteristic (ROC) curve. An area under the curve (AUC) of 0.5 suggests that the model lacks discriminative capability, whereas an AUC of 1.0 indicates a perfect test with both sensitivity and specificity at 100%. Generally, AUC values exceeding 0.8 are regarded as indicative of strong discriminative ability. This model had an AUC of 0.92 (95% CI: 0.84–0.99), a sensitivity of 0.88 (95% CI: 0.80–0.97), a specificity of 0.88 (95% CI: 0.71–1.00), and an accuracy of 0.88 (95% CI: 0.78–0.95) (Fig. 4). Model calibration refers to its ability to accurately predict the outcome variable across patient subgroups. We used this calibration plot to assess the accuracy of the nomogram for colorectal perforation mortality risk. Figure 5 shows the relationship between observed and predicted mortality rates, indicating the model's effectiveness in accurately predicting the risk of patient mortality. The Hosmer−Lemeshow chi-square test yielded a non-significant result for the nomogram (3.15, P = 0.924), suggesting no substantial difference between the observed and anticipated case numbers. The predicted mortality rates are on the x-axis, while the actual observed outcomes are plotted along the y-axis. The calibration curve shows that the predicted probabilities are essentially consistent with the observed probabilities, indicating that the model has a good fit (a perfect prediction would be along a straight line at a 45° angle to each axis).

The clinical usefulness of the prediction model was evaluated using decision curve analysis (Fig. 6). Results indicate that when the probability exceeds the 2% threshold, the net benefit of the prediction model is greater than that of

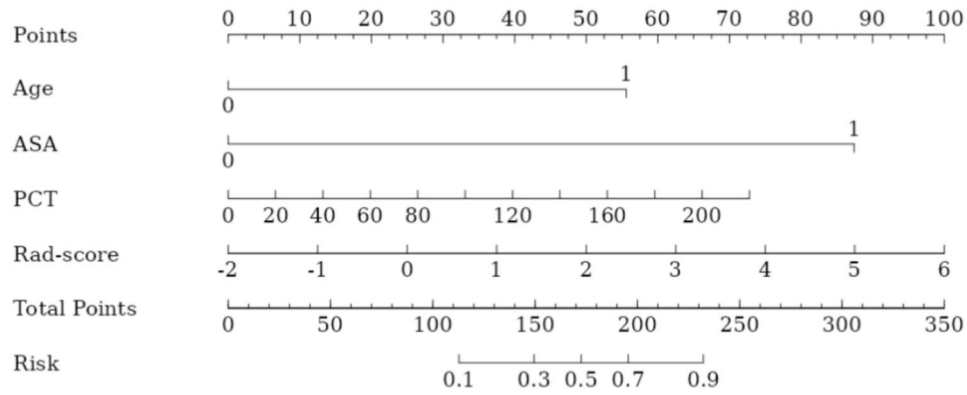

Fig. 3 Flowchart of CT image acquisition and model construction

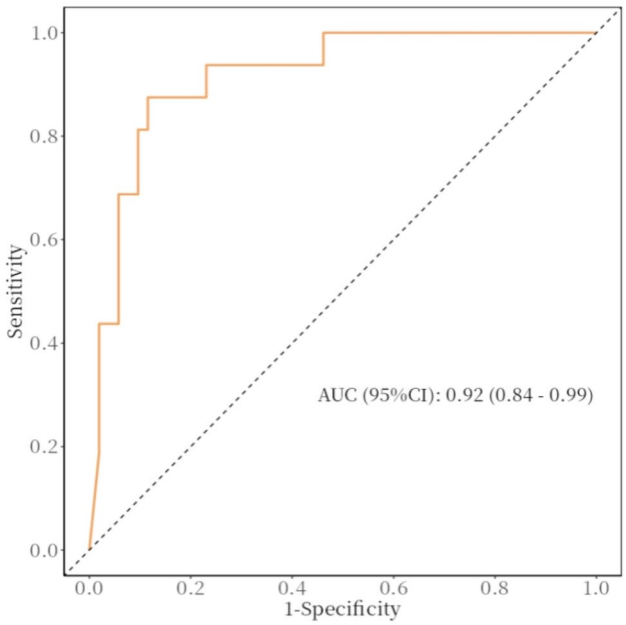

Fig. 4 The nomogram's predictive accuracy was evaluated via the ROC curve in the validation cohort

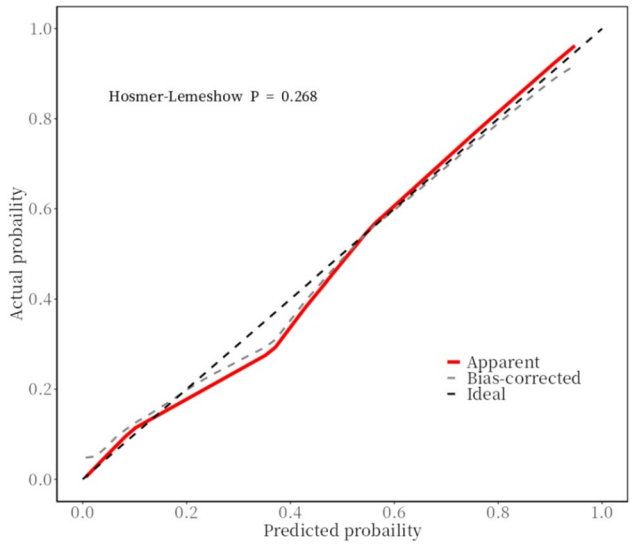

Fig. 5 Hosmer–Lemeshow calibration plot

the other two lines, suggesting that the model has practical value. When the red curve is very close to or overlaps with the 'All' and 'None' lines, which represent extreme scenarios, the model may have lower application value.

Discussion

Colorectal perforation has a poor prognosis, with the majority of patients ultimately dying from severe septic shock due to fecal peritonitis. Despite advances in postoperative management, predicting mortality via readily available preoperative parameters remains crucial. Predicting postoperative mortality via readily accessible clinical data preoperatively is highly significant, both for clarifying postoperative risks to patients' families and for the management of such patients postoperatively. We discovered four key clinical indicators during the perioperative period that correlate with death rates after colorectal perforation. In our model, three indicators are readily available from routine preoperative tests without the need for additional examinations, which enhances the practicality of the model in clinical settings. A new predictive tool based on four significant risk factors is suggested due to its strong accuracy in forecasting mortality in our study. Several predictive factors have been suggested for predicting postoperative outcomes in colorectal perforation patients. Sumi et al. reported that age is an important prognostic factor, possibly because organ function generally decreases in elderly patients [[24]]. This aligns with our finding that age ≥ 75 years is a significant predictor of mortality. Matsuoka et al. reported that plasma albumin levels and decreased platelet counts are significant

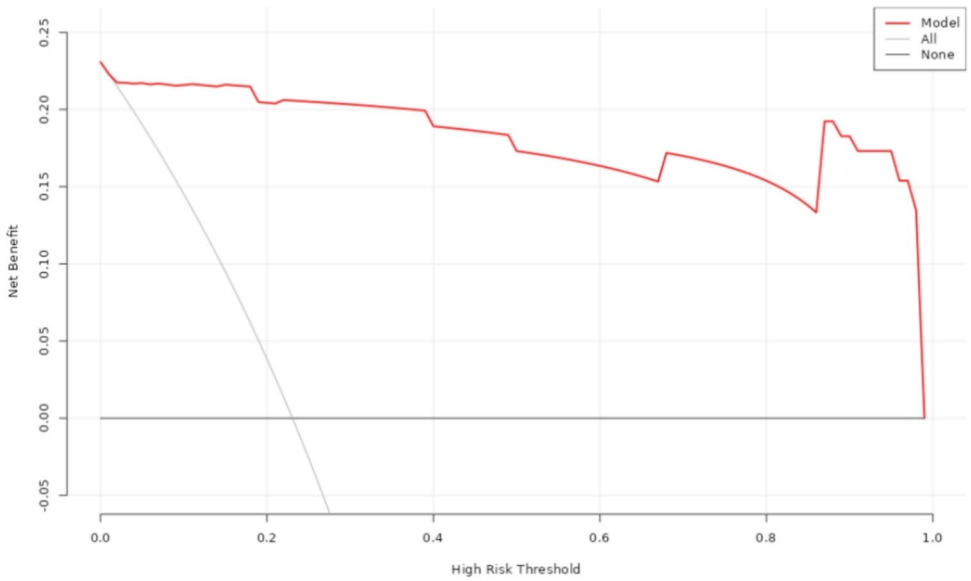

Fig.6 Clinical decision curve for the mortality risk nomogram model in patients with colorectal perforation. (The x-axis indicates the threshold probability, while the y-axis shows the net benefit.)

predictors of short-term mortality [[25]]. In contrast, our study found that procalcitonin (PCT) levels and radiomics scores were independently associated with mortality. These differences may be attributed to variations in study populations and the inclusion of radiomics features in our model, which were not considered in previous studies.

When intestinal perforation occurs, the integrity of the intestinal wall is compromised, resulting in the leakage of fluids into the abdominal cavity. Furthermore, the contents or bacteria from the perforated intestine can induce acute peritonitis and abdominal infection, which in turn lead to the formation of inflammatory exudate and ascites. Drakopoulos et al. reported that CT can be used to assess the site of perforation effectively [[26]]. We identified ascites in 68 out of the 104 cases reviewed (65.4%), most of which were located next to the pelvic floor, similar to the results published by Drakopoulos et al. Additionally, univariate and multivariate analyses revealed that radiomics scores based on CT fluid accumulation characteristics are potential prognostic predictors. In this study, we utilized 3D Slicer software for the segmentation and 3D reconstruction of medical images, enabling precise analysis of anatomical structures. Currently, 3D Slicer is being used in an increasing number of studies to assist in constructing and validating prognostic models on the basis of radiomic features. Tang et al. utilized 3D Slicer and the least absolute shrinkage and selection operator (LASSO) algorithm for radiomic texture feature selection, constructing a model based on clinical risk characteristics and CT imaging to predict lymph node metastasis (LNM) and prognosis in patients with duodenal papillary carcinoma (DPC) [[27]]. Margaux et al. used 3D Slicer software to segment the preoperative CT images of patients with pancreatic neuroendocrine tumors to identify the region of interest (ROI). Radiomic features were subsequently extracted from these three-dimensional images to construct a model for predicting disease-free survival (DFS) [[28]].

These scoring systems enable objective and methodical assessments of the seriousness of colorectal perforation, and several past studies have evaluated systems such as POSSUM, P-POSSUM, SOFA, APACHE II, MPI, and ASA, for predicting the prognosis of patients undergoing surgery for colorectal perforation. Nakamura et al. Reported that the SOFA and POSSUM scores are significant markers of mortality according to univariate analysis [[29]]. The Acute Physiology and Chronic Health Evaluation II (APACHE II) is the most widely used severity of illness scoring system in intensive care units (ICUs) worldwide. Multivariate analysis revealed that score as an independent prognostic indicator for mortality, as reported by Ishikawa et al. They combined 3D-based dirty mass volume reconstruction with APACHE II scores to stratify the risk of death rates after colorectal perforation surgery [[30]]. However, it is not currently used alone to predict the prognosis of patients with colorectal perforation, and the data required are numerous and not easily obtainable. The Mannheim peritonitis index (MPI) can be used to predict the risk of mortality from peritonitis of any cause. It is easy to calculate and has high sensitivity and specificity. The MPI index primarily reflects the current severity of peritonitis and does not include factors such as age or comorbidities such as cardiovascular diseases. According to prospective research by Jobin et al., the integration of the MPI with 24-h lactate values emerges as the premier indicator for forecasting mortality in cases of perforation peritonitis [[31]].

In our study, a nomogram model was developed using four simple variables: age, ASA classification, PCT, and the radiomics score. In the nomogram, the impact of each variable on the death rate among patients with colorectal

perforation is reflected by the points corresponding to their respective coordinates; the points for each factor are added together to produce the model's total score. By referring to the total score, one can determine the probability of death for a perforated patient, which represents the risk of mortality for that individual. Before being applied clinically, the associations of radiomic and clinical characteristic scores with mortality must be validated and confirmed for reproducibility in broader center data collections. Further prospective studies are needed to identify the most suitable therapy plan. Future research should focus on validating the predictive model in diverse populations to assess its generalizability. Additionally, exploring the impact of specific interventions based on the risk stratification provided by the nomogram could offer valuable insights into improving patient outcomes. Further studies could also investigate the potential integration of additional radiomic features or clinical parameters to further enhance model performance.

A constraint in our research is the modest number of participants, potentially impacting the broader applicability of our results. A limitation of our analysis is the reliance on self-reported data, which is subject to recall bias and may not accurately reflect actual behavior. During the data processing, we used the median imputation method for individual missing values. This method is simple but may not capture the variability in the data. The long recruitment period may have introduced variability in patient management and treatment approaches over time, affecting the consistency of our results. Future studies with larger sample sizes and more centers are needed to confirm our preliminary findings and to further explore the relationships among the variables of interest.

Conclusions

The results of this study show that the combination of radiomic scores and clinical characteristics serves as a reliable predictor of postoperative mortality in patients with colorectal perforation. This model is applicable not only to the cohort from which it was developed but also to similar patients from different geographical locations over different time periods.

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Author contributions Jiaqing Lin, Kun Yang and Zhaopu Li contributed to study design or coordination. Jiaqing Lin and Kun Yang contributed to data acquisition. Jiaqing Lin and Zhaopu Li contributed to data analysis. Jiaqing Lin, Kun Yang, Yang Li, Wei Zhu and Zhaopu Li contributed to data interpretation. All authors contributed to the edits of the manuscript. Kun Yang supervised the project.

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Data availability The datasets generated and/or analysed during the current study are not publicly available due to privacy and confidentiality concerns, as the data contain sensitive personal information of patients, but are available from the corresponding author on reasonable request.

Declarations

Approval of the research protocol This study was approved by the institutional review board of Xiaogan Central Hospital (approval no. 2024091401).

Patient and public involvement No patient and public involvement. The study was conducted using de-identified patient data, and the requirement for informed consent was waived by the Institutional Review Board due to the retrospective nature of the study.

Informed consent N/A.

Registry and the registration no. of the study/trial N/A.

Competing interests The authors declare no competing interests.

References

1. Bielecki K, Kamiński P, Klukowski M (2002) Large bowel perforation: morbidity and mortality. Tech Coloproctol 6(3):177–182. https://doi.org/10.1007/s101510200039
2. Sartelli M, Catena F, Ansaloni L et al (2014) Complicated intra-abdominal infections worldwide: the definitive data of the CIAOW Study. World J Emerg Surg 9:37. https://doi.org/10.1186/1749-7922-9-37
3. de'Angelis N, Di Saverio S, Chiara O, et al (2018) 2017 WSES guidelines for the management of iatrogenic colonoscopy perforation. World J Emerg Surg 13:5. https://doi.org/10.1186/s13017-018-0162-9
4. Cirocchi R, Trastulli S, Desiderio J et al (2013) Treatment of Hinchey stage III–IV diverticulitis: a systematic review and

meta-analysis. Int J Colorectal Dis 28(4):447–457. https://doi.org/10.1007/s00384-012-1622-4
5. Yamamoto T, Kita R, Masui H et al (2015) Prediction of mortality in patients with colorectal perforation based on routinely available parameters: a retrospective study. World J Emerg Surg 10:24. https://doi.org/10.1186/s13017-015-0020-y
6. Biondo S, Ramos E, Deiros M, Ragué JM, De Oca J, Moreno P, Farran L, Jaurrieta E (2000) Prognostic factors for mortality in left colonic peritonitis: a new scoring system. J Am Coll Surg 191(6):635–642. https://doi.org/10.1016/s1072-7515(00)00758-4
7. Lambrichts DPV, Vennix S, Musters GD et al (2019) Hartmann's procedure versus sigmoidectomy with primary anastomosis for perforated diverticulitis with purulent or fecal peritonitis (LADIES): a multicentre, parallelgroup, randomised, open-label, superiority trial. Lancet Gastroenterol Hepatol 4(8):599–610. https://doi.org/10.1016/S2468-1253(19)30174-8
8. Haas JM, Singh M, Vakil N (2016) Mortality and complications following surgery for diverticulitis: Systematic review and meta-analysis. United European Gastroenterol J 4(5):706–713. https://doi.org/10.1177/2050640615617357
9. Sartelli M, Coccolini F, Catena F et al (2020) 2020 update of the WSES guidelines for the management of acute colonic diverticulitis in the emergency setting. World J Emerg Surg 15(1):32. https://doi.org/10.1186/s13017-020-00313-4
10. Tan KK, Hong CC, Zhang J, Liu JZ, Sim R (2011) Predictors of outcome following surgery in colonic perforation: an institution's experience over 6 years. J Gastrointest Surg 15(2):277–284. https://doi.org/10.1007/s11605-010-1330-8
11. Kawai K, Hiramatsu T, Kobayashi R et al (2007) Coagulation disorder as a prognostic factor for patients with colorectal perforation. J Gastroenterol 42(6):450–455. https://doi.org/10.1007/s00535-007-2027-y
12. Horiuchi A, Watanabe Y, Doi T, et al (2007) Evaluation of prognostic factors and scoring system in colonic perforation. World J Gastroenterol. 13(23):3228–31. https://doi.org/10.3748/wjg.v13.i23.3228.
13. Kriwanek S, Armbruster C, Beckerhinn P, Dittrich K (1994) Prognostic factors for survival in colonic perforation. Int J Colorectal Dis 9(3):158–162. https://doi.org/10.1007/BF00290194
14. Shimazaki J, Motohashi G, Nishida K, Ubukata H, Tabuchi T (2014) Postoperative arterial blood lactate level as a mortality marker in patients with colorectal perforation. Int J Colorectal Dis 29(1):51–55. https://doi.org/10.1007/s00384-013-1738-1
15. Lyons PG, Micek ST, Hampton N, Kollef MH (2018) Sepsis-Associated Coagulopathy Severity Predicts Hospital Mortality. Crit Care Med 46(5):736–742. https://doi.org/10.1097/CCM.0000000000002997
16. Cirocchi R, Afshar S, Di Saverio S et al (2017) A historical review of surgery for peritonitis secondary to acute colonic diverticulitis: from Lockhart-Mummery to evidence-based medicine. World J Emerg Surg 12:14. https://doi.org/10.1186/s13017-017-0120-y
17. Kudou K, Kusumoto T, Ebata Y et al (2022) Prediction of hospital mortality after colorectal perforation surgery from inflammation-based prognostic scores. Surg Open Sci 8:40–46. https://doi.org/10.1016/j.sopen.2022.01.003
18. Aerts HJ, Velazquez ER, Leijenaar RT et al (2014) Decoding tumor phenotype by noninvasive imaging using a quantitative radiomics approach. Nat Commun 5:4006. https://doi.org/10.1038/ncomms5006
19. Deng K, Chen T, Leng Z et al (2024) Radiomics as a tool for prognostic prediction in transarterial chemoembolization for hepatocellular carcinoma: a systematic review and meta-analysis. Radiol Med 129(8):1099–1117. https://doi.org/10.1007/s11547-024-01840-9
20. Bortolotto C, Lancia A, Stelitano C et al (2021) Radiomics features as predictive and prognostic biomarkers in NSCLC. Expert Rev Anticancer Ther 21(3):257–266. https://doi.org/10.1080/14737140.2021.1852935
21. Schniering J, Maciukiewicz M, Gabrys HS et al (2022) Computed tomography-based radiomics decodes prognostic and molecular differences in interstitial lung disease related to systemic sclerosis. Eur Respir J 59(5):2004503. https://doi.org/10.1183/13993003.04503-2020
22. Fedorov A, Beichel R, Kalpathy-Cramer J et al (2012) 3D Slicer as an image computing platform for the Quantitative Imaging Network. Magn Reson Imaging 30(9):1323–1341. https://doi.org/10.1016/j.mri.2012.05.001
23. Simmross-Wattenberg F, Carranza-Herrezuelo N, Palacios-Camarero C et al (2005) Group-Slicer: a collaborative extension of 3D-Slicer. J Biomed Inform 38(6):431–442. https://doi.org/10.1016/j.jbi.2005.03.001
24. Sumi T, Katsumata K, Katayanagi S et al (2014) Examination of prognostic factors in patients undergoing surgery for colorectal perforation: a case controlled study. Int J Surg 12(6):566–571. https://doi.org/10.1016/j.ijsu.2014.03.021
25. Matsuoka T, Yamamoto R, Matsumura K et al (2022) Perioperative clinical parameters associated with short-term mortality after colorectal perforation. Eur J Trauma Emerg Surg 48(4):3017–3024. https://doi.org/10.1007/s00068-021-01719-8
26. Drakopoulos D, Arcon J, Freitag P et al (2021) Correlation of gastrointestinal perforation location and amount of free air and ascites on CT imaging. Abdom Radiol (NY) 46(10):4536–4547. https://doi.org/10.1007/s00261-021-03128-2
27. Tang CT, Wu Y, Jiang L, Zeng CY, Chen YX (2024) Radiomics analysis based on CT for predicting lymph node metastasis and prognosis in duodenal papillary carcinoma. Insights Imaging 15(1):155. https://doi.org/10.1186/s13244-024-01732-6
28. Homps M, Soyer P, Coriat R et al (2023) A preoperative computed tomography radiomics model to predict disease-free survival in patients with pancreatic neuroendocrine tumors. Eur J Endocrinol 189(4):476–484. https://doi.org/10.1093/ejendo/lvad130
29. Nakamura F, Yui R, Muratsu A, Sakuramoto K, Muroya T, Ikegawa H, Kuwagata Y (2019) Study of the prognostic factor of the colon perforation case with the pan-peritonitis that needed emergency surgery: a single-center observational study. Acute Med Surg 6(4):379–384. https://doi.org/10.1002/ams2.429
30. Ishikawa D, Takehara Y, Takata A, Takamura K, Sato H (2021) Combination of dirty mass volume and APACHE II score predicts mortality in patients with colorectal perforation. World J Emerg Surg 16(1):17. https://doi.org/10.1186/s13017-021-00359-y
31. Jobin SP, Maitra S, Baidya DK, Subramaniam R, Prasad G, Seenu V (2019) Role of serial lactate measurement to predict 28-day mortality in patients undergoing emergency laparotomy for perforation peritonitis: prospective observational study. J Intensive Care 7:58. https://doi.org/10.1186/s40560-019-0418-9