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ORIGINAL ARTICLE

A Risk Score for Predicting the Necessity of Surgical Necrosectomy in the Treatment of Infected Necrotizing Pancreatitis

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Abstract

Background For infected necrotizing pancreatitis (INP), percutaneous catheter drainage (PCD) is now widely acknowledged as the initial intervention in a step-up approach, followed, if necessary, by minimally invasive necrosectomy or even open pancreatic necrosectomy. However, an overemphasis on PCD may cause a patient's condition to deteriorate, leading to missed surgical opportunities or even death. This study aimed to develop a simple and convenient scoring tool for assessing the need for surgery in INP patients who received PCD procedures.

Methods In an observational study conducted between April 2015 and December 2020, PCD was utilized as the initial step to treat 143 consecutive INP patients. A surgical necrosectomy was performed when the patient failed to respond. Risk factors of PCD failure (i.e., need for surgical necrosectomy) were identified by multivariate logistic regression models. An integer-based risk scoring tool was developed using the β coefficients derived from the logistic regression model.

Results In 62 (43.4%) patients, PCD was successful, while the remaining 81 (56.6%) individuals required subsequent surgical necrosectomy. In the multivariate model, organ failure, percentage of pancreatic necrosis, extrapancreatic necrosis volume, and mean CT density of extrapancreatic necrosis volume were associated with a need for surgical necrosectomy. A predictive scoring tool based on these four factors demonstrated an area under the receiver operating characteristic curve (AUC) of 0.893. Under the scoring tool, a total score of 4 or more indicates a high possibility of surgical necrosectomy being required (at least 80%). Using the coordinates of the receiver operating characteristic curve (ROC), the sensitivity and specificity at this threshold are 0.802 and 0.903, respectively.

Conclusions A risk score model integrating organ failure, percentage of pancreatic necrosis, extrapancreatic necrosis volume, and mean CT density of extrapancreatic necrosis volume can identify INP patients at high risk for necrosectomy. The straightforward risk assessment tool assists clinicians in stratifying INP patients and making more judicious medical decisions.

Keywords Infected necrotizing pancreatitis · Percutaneous catheter drainage · Surgical necrosectomy · Risk score

Introduction

The severity of acute pancreatitis (AP) can range from clinically self-limiting to life-threatening.[1,2] Among the different progressions of AP, necrotizing pancreatitis (NP) stands out as the most severe, with a dismal prognosis. Mortality rates approximate 15%, escalating up to 30% in cases of infected necrotizing pancreatitis (INP), which often culminates in sepsis and multiple organ failure, and serves as the primary catalyst for mortality and severe complications.[3]

The interventional strategy for NP should be postponed as long as possible, preferably until 4 weeks after disease onset.[3,4] Similarly, the management approaches for INP have undergone significant changes over the past two decades and continue to advance, driven by expanding experience, introduction of new treatments, and ongoing research. While major surgical intervention and debridement used to be the primary therapeutic approach for patients with symptomatic necrotic collections, a paradigm shift has occurred with the emergence of the step-up approach that incorporates minimally invasive procedures for INP treatment.[3,5]

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Percutaneous catheter drainage (PCD) has now gained widespread acceptance as the initial intervention in the step-up approach, followed by minimally invasive debridement or even open pancreatic necrosectomy if required to effectively manage the condition. Undoubtedly, PCD is preferred for certain patients due to its minimal surgical trauma and ability to avoid approximately one-third of surgical debridement. However, patients with NP should receive personalized care considering the unique nature of their circumstances.

It is crucial to avoid an excessive emphasis on PCD, as it can result in the deterioration of a patient's condition, leading to missed opportunities for surgery or even fatalities.[6,7] Consequently, a common clinical scenario arises where surgery is not entirely excluded but rather delayed. Surgical debridement proves to be more effective than PCD; hence, accurately predicting PCD failure is of utmost importance since some patients may benefit from direct surgical intervention. Regrettably, only a limited number of prediction models have been proposed to estimate the risk of PCD-treated patients requiring surgical necrosectomy. In the present study, our objective was to develop a straightforward and convenient scoring system that assesses the necessity for surgery in patients with INP, thereby aiding in developing an individualized therapeutic strategy.

Methods

Population Selection

This was an observational cohort study with retrospective analysis of a prospectively maintained database of patients with confirmed or suspected INP in the department of Pancreas Center, the First Affiliated Hospital of Nanjing Medical University (Nanjing, China). The study was conducted between April 2015 and December 2020. Patients were excluded if they had previously undergone drainage or surgery to treat confirmed or suspected infected necrosis, as well as if they had suffered from an acute intraabdominal event (e.g., bleeding, perforation of a visceral organ, or abdominal compartment syndrome). This study was approved by the Ethics Committee of First Affiliated Hospital of Nanjing Medical University (No. 2022-NT-12). Written informed consent was waived due to the retrospective study design.

Definitions

AP was diagnosed according to the revised Atlanta criteria.[8] INP was determined by the presence of free gas within the pancreatic and peripancreatic necrosis on contrast-enhanced computed tomography (CECT) or a positive culture at fine-needle aspiration (FNA). The definition of suspected INP is persistent fever and/or general deterioration despite maximal conservative treatment 14 days following the onset of AP.[9] Organ failure was defined as a score of 2 or greater for the respiratory, cardiovascular, or renal systems using the modified Marshall scoring system.[8] In accordance with the number of failed systems, single organ failure and multiple organ failures were configured, respectively. According to the revised Atlanta classification, a complete encapsulated collection of pancreatic and/or peripancreatic necrosis develops a well-defined inflammatory wall, i.e., walled-off necrosis (WON).

Imaging Evaluation

Pancreatic necrosis was defined as an area of diminished or no enhancement of the pancreatic parenchyma on CECT. Extrapancreatic necrosis included peripancreatic necrosis and contiguous retroperitoneal fat necrosis.[10] The volume of extrapancreatic necrosis was measured with manual segmentation using IntelliSpace Portal software and workstation (Philip Corporation, Amsterdam, the Netherlands) and is presented in Fig. 1. The mean CT density of extrapancreatic necrosis was measured and calculated using MDC PACS Viewer System (Philip Corporation, Amsterdam, the Netherlands) and presented as contrast density (Hounsfield units, or HU). The valid mean CT density for patients with separated lesions was equal to the maximum index of those multi-sited lesions. The clinical information and the outcome criteria were hidden from the expert radiologist with at least 6 years of experience who reviewed all abdomen CT scans.

Procedures

Initially, all enrolled patients received conservative medical treatment, including resuscitation measures, enteral feeding (or oral), and empirical or targeted antibiotic therapy. In case of failure to improve with conservative management, insertion of PCD was performed under radiologic guidance (B ultrasonic- or CT-guided). The number of catheters inserted into a cavity was determined by the imaging results and clinical manifestations. The primary PCD was considered a success if patients improved clinically and a reduced amount of pancreatic and/or extrapancreatic necrosis was confirmed by CT reassessment 72 h later. If a patient failed to recover clinically following PCD, the collection was evaluated radiologically (usually after 72 h) and, if necessary, drains were relocated and/or news drains were inserted. A surgical necrosectomy was performed if the patient still failed to improve clinically despite adequately positioned drains. Additionally, if there were no suitable puncture routes for catheter implantation, a primary surgical necrosectomy was performed directly.

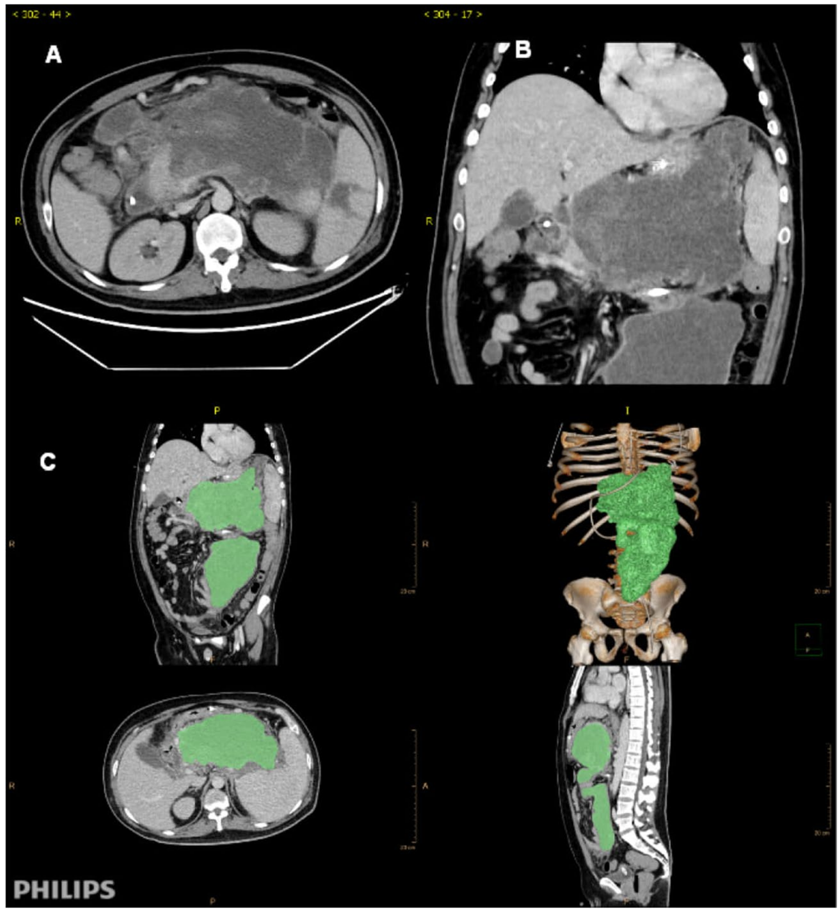

Fig. 1 The CT image analysis workflow. **A** and **B** An extensive amount of extrapancreatic necrotic material was visible on the axial (**A**) and coronal (**B**) CT images. **C** Analysis of extrapancreatic necrosis volume using Philips IntelliSpace Portal software

For surgical debridement, we use uni-/bilateral flank incisions (retroperitoneal) and/or micro transverse incisions (transperitoneal) or an upper abdominal midline incision. The choice of incision is flexible and depends on the location and extension of necrosis. After blunt removal of the necrotic tissue, some large-bore drainage tubes were then placed for postoperative lavage. The outcomes were recorded, including the incidence of surgical complications (within 1 month) and in-hospital death.

Data Collection

Relevant variables were collected from the databases for the study. As potential predictors of the necessity of surgical necrosectomy after PCD, the following variables were selected: (1) demographic parameters, including sex, age, body mass index (BMI), and etiology; (2) disease severity parameters 24 or fewer hours before PCD, including white blood cell (WBC) count, serum C-reactive protein (CRP), procalcitonin (PCT), and the number of failing organs; (3) necrotic features in the CECT images, including the percentage of pancreatic necrosis, the total volume, and the mean CT density of the extrapancreatic necrosis; and (4) drainage parameters, including days from onset of AP to first PCD, size of primary catheter drain, and upsizing primary catheter drain to larger drain.

Statistical Analysis

The data were analyzed using the software R and EmpowerStats (http://www. empowerstats.com, X&Y Solutions, Inc., Boston, MA). Continuous variables were presented as the mean and standard deviation (SD) for the normal distribution or median/quartile for the non-normal distribution. Categorical variables were presented as frequency and percentage. The logistic regression analysis was used to identify variables associated with the necessity of surgical necrosectomy after PCD. Factors with $P < 0.1$ in univariable logistic regression were considered for inclusion in the multivariable model. The final model was constructed using backward stepwise elimination with a threshold P-value of 0.05. Results were presented as odds ratio (OR) with 95 % confidence interval (CI). P values (2-tailed) < 0.05 were considered statistically significant. The performance of the prediction model was assessed in receiver operating characteristic (ROC) curves with calculations of the area under the curve (AUC). Bootstrapping with 1000 resamples was used for internal validation. Regression coefficients for each predictor in the final model were converted to whole numbers by dividing each item coefficient by the lowest value coefficient. A simplified scoring tool for the best performing model was derived to give a probability of needing surgical debridement. Scores were presented alongside their associated predicted probabilities.

Results

Patients and Outcomes

A total of 181 patients with suspected or confirmed infected necrosis were included in the study. Seven of these patients were cured by systemic antibiotics alone and therefore did not need PCD or surgery. Of the remaining patients, 143 received PCD as a step-up treatment strategy for the initial intervention, whereas 31 underwent upfront surgery (due to a lack of an appropriate PCD route in 17 patients and abdominal emergencies such as bleeding, bowel perforations, and abdominal compartment syndrome in 14 patients). The 143 patients who were initially treated with PCD constituted the final study cohort. The initial PCD procedure was carried out 31 days following the onset of AP. Eighty-six patients (60.1%) received single catheter drainage, while the remaining 57 (39.9%) received two or more catheter drains. In 28 patients, the catheter drains were up-sized to larger catheter drains. In 126 individuals (88.1%), infection of walled-off necrosis was established by the presence of gas bubbles within the cavity on CT or by a positive culture of fluid obtained from the cavity through FNA or catheter drainage. In this study, 62 patients (43.4%) were treated solely with PCD and survived without undergoing necrosectomy. Surgical necrosectomy was performed on an additional 81 patients (56.6%), with the first necrosectomy being performed 39 days after the onset. Out of these 81 patients, 72 were cured, but nine died due to uncontrolled bleeding or sepsis, which were the leading causes of mortality.

Risk Factors and Prediction Factors of Surgical Necrosectomy

Table 1 shows the prevalence of the investigated factors in the study. Univariate logistic regression analysis identified six variables that may be associated with the need for surgical necrosectomy: complete encapsulation, upsizing of first PCD, organ failure, percentage of pancreatic necrosis, extrapancreatic necrosis volume, and mean CT density of extrapancreatic necrosis ($P<0.1$; Table 2). Subsequently, further analysis was conducted by introducing these six identified variables in a multivariate logistic regression model. The results showed that organ failure, percentage of pancreatic necrosis, extrapancreatic necrosis volume, and mean CT density of extrapancreatic necrosis volume were independent risk factors for the need for surgical debridement after PCD in INP patients ($P<0.05$; Table 2).

Table 1 Baseline characteristics and clinical parameters of enrolled patients by study group (*N*=143)

Variables	Values
Age (years), mean ± (SD)	50.1 ± 15.0
Sex (male), *n* (%)	95 (66.4%)
BMI (Kg/m^2), mean ± (SD)	24.2 ± 2.7
Etiology, *n* (%)	
Biliary	55 (38.5%)
Alcoholic	34 (23.8%)
Hypertriglyceridemia	32 (22.4%)
Others	22 (15.4%)
Organ failure, *n* (%)	
No organ failure	74 (51.7%)
Single organ failure	46 (32.2%)
Multiple organ failure	23 (16.1%)
WBC(×10^9/L), mean ± (SD)	14.8 ± 5.4
CRP (mg/L), mean ± (SD)	176.3 ± 70.0
PCT (μg/L), mean ± (SD)	3.8 ± 2.9
Percentage of pancreatic necrosis	
<30%	71 (49.7%)
30–50%	43 (30.1%)
>50%	29 (20.3%)
Site of necrotic collection, *n* (%)	
Central	28 (19.6%)
Left and/or right	63 (44.1%)
Combined	52 (36.4%)
Extrapancreatic necrosis volume (ml), mean ± (SD)	823.2 ± 414.3
Mean CT density of extrapancreatic necrosis(HU), mean ± (SD)	24.6 ± 6.6
Complete encapsulation, *n* (%)	97 (67.8%)
Onset to PCD (days), mean ± (SD)	30.7 ± 11.6
First PCD size (Fr), mean ± (SD)	12.7 ± 2.1
Upsizing to larger drain, *n* (%)	28 (19.6%)
Number of PCD performed	
1	86 (60.1%)
≥2	57 (39.9%)

BMI, body mass index; *WBC*, white blood cell; *CRP*, C-reactive protein; *PCT*, procalcitonin; *PCD*, percutaneous catheter drainage; *SD*, standard deviation

Model Development

Based on the independent risk factors mentioned above, we developed a predictive model. The discrimination, accuracy, and practicability of the model were evaluated using the ROC curve, calibration curve, and decision curve analysis (DCA), respectively. The model demonstrated excellent discrimination, with an AUC

Table 2 Logistic regression analysis for independent risk factors of the need for surgical necrosectomy with score generation

Variables	Univariable		Multivariable			
	OR (95% CI)	*P* value	OR (95% CI)	*P* value	Coefficient	Score assigned
Age	1.0 (1.0–1.0)	0.784	-	-	-	-
Sex			-	-	-	-
Male	Reference		-	-	-	-
Female	0.8 (0.4–1.5)	0.435	-	-	-	-
BMI	1.0 (0.8–1.1)	0.431	-	-	-	-
Etiology						
Biliary	Reference		-	-	-	-
Alcoholic	1.0 (0.4–2.4)	0.952	-	-	-	-
Hypertriglyceridemia	0.7 (0.3–1.7)	0.460	-	-	-	-
Others	1.0 (0.4–2.8)	0.942	-	-	-	-
Organ failure						
No organ failure	Reference		Reference			0
Single organ failure	4.2 (1.9–9.2)	<0.001	3.6 (1.3–10.0)	0.016	1.27090	1
Multiple organ failure	11.0 (3.0–40.2)	<0.001	9.3 (1.9–46.3)	0.007	2.22790	2
WBC	1.0 (1.0–1.1)	0.605	-	-	-	-
CRP	1.0 (1.0–1.0)	0.658	-	-	-	-
PCT	1.0 (0.9–1.2)	0.475	-	-	-	-
Percentage of pancreatic necrosis						
<30%	Reference		Reference			0
30–50%	6.9 (2.9–16.4)	<0.001	4.1 (1.4–11.9)	0.01	1.40392	1
>50%	13.0 (4.1–41.9)	<0.001	11.2 (2.6–47.0)	0.001	2.41197	2
Site of necrotic collection						
Central	Reference		-	-	-	-
Left and/or right	1.2 (0.5–2.8)	0.751	-	-	-	-
Combined	1.2 (0.5–3.0)	0.723	-	-	-	-
Extrapancreatic necrosis volume						
<500	Reference		Reference			0
500–999	2.6 (1.1–5.7)	0.021	4.7 (1.5–14.6)	0.008	1.53809	1
≥1000	6.2 (2.4–16.3)	<0.001	8.6 (2.4–31.0)	0.001	2.14613	2
Mean CT density of extrapancreatic necrosis						
<25	Reference		Reference			0
≥25	6.3 (3.0–13.2)	<0.001	8.4 (3.1–22.9)	<0.001	2.13362	2
Complete encapsulation						
No	Reference		-	-	-	-
Yes	0.5 (0.2–1.1)	0.076	-	-	-	-
Onset to PCD	1.0 (1.0–1.0)	0.357	-	-	-	-
First PCD size	1.0 (0.9–1.2)	0.717	-	-	-	-
Upsizing to larger drain						
No	Reference		-	-	-	-
Yes	2.2 (0.9–5.4)	0.083	-	-	-	-
Number of PCD performed						
1	Reference		-	-	-	-
≥2	1.2 (0.6–2.4)	0.555	-	-	-	-

BMI, body mass index; *WBC*, white blood cell; *CRP*, C-reactive protein; *PCT*, procalcitonin; *PCD*, percutaneous catheter drainage; *OR*, odds ratio; *CI*, confidence interval

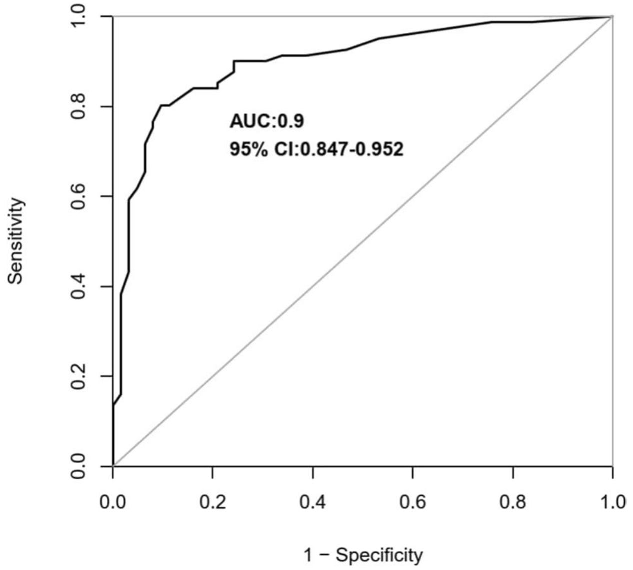

Fig. 2 ROC of the multivariable regression model for predicting the need for surgical necrosectomy. It includes predictors of organ failure, percentage of pancreatic necrosis, extrapancreatic necrosis volume, and mean CT density of extrapancreatic necrosis. The AUC was 0.9, indicating high diagnostic accuracy for the predictive model of four significant variables. ROC, receiver operating characteristic curve; AUC, area under the receiver operating characteristic curve

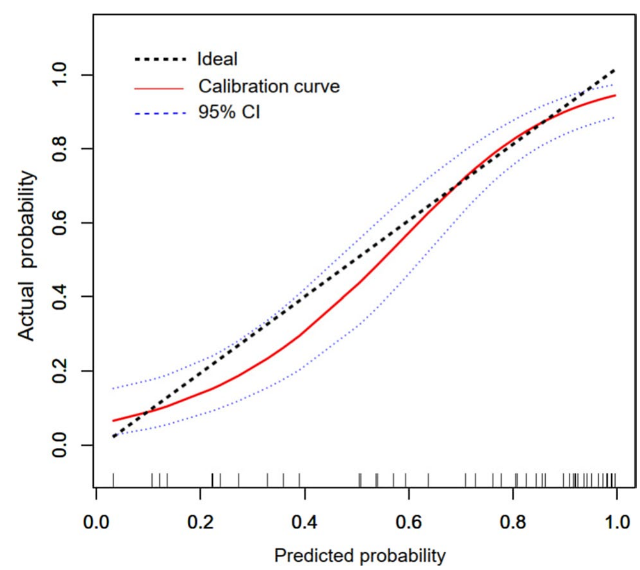

Fig. 3 Calibration plot for the predictive model. The 45-degree black dotted line represents the situation where the predicted probability is exactly the same as the actual probability. The red smoothed curve represents the actual incidence of the need for surgical necrosectomy at different predictive probabilities, which has a closer fit to the ideal line indicating a better prediction. The blue dotted line represents a 95% confidence interval (95% CI)

of 0.9 (Fig. 2). Internal validation using the bootstrap resampling strategy (1000 resamples) showed an AUC of 0.899, indicating good discrimination of the established model in predicting the need for surgical necrosectomy. Moreover, the calibration curve indicated that the model provided well-fitted predictions and observed probabilities (Fig. 3). The DCA revealed a positive net benefit for a threshold probability ranging from 10 to 95% (Fig. 4).

To enhance model performance, we developed a simple scoring method by converting the beta coefficient values of the four identified predictors into integers. Each patient's four variables will be assigned a score (Table 2), and these scores will be summed to calculate the individual's total score, which indicates the likelihood of requiring surgical debridement (Table 3). The total risk score ranged from 0 (lowest risk) to 8 (highest risk). The predicted probability of requiring surgical necrosectomy corresponding to each total score was calculated. The prediction scoring tool achieved an AUC of 0.893. According to this clinical diagnostic model, a score of 4 or higher indicates a high likelihood of requiring surgical necrosectomy, with a minimum probability of 80% (Table 3). By using the coordinates from the ROC curve, the sensitivity and specificity at this threshold were calculated as 0.802 and 0.903, respectively.

Discussion

In recent years, the management of NP patients requiring intervention has seen a significant paradigm shift favoring minimally invasive approaches as initial therapy. Minimally invasive "step-up" approach could result in fewer adverse events than the open pancreatic necrosectomy.[11–13] PCD, often considered the first step in the "step-up" approach, could avoid unnecessary surgery in 35% of patients with IPN.[13] Unfortunately, PCD treatment often fails due to the severity of the patient's condition (e.g., massive solid necrotic material, sepsis, organ failure). A study by Harfouche et al.[14] indicates that patients who experience a drainage failure during the treatment of NP have a higher risk of morbidity and mortality than those who undergo surgery as the primary treatment. In this study, individuals with a high Acute Physiology and Chronic Health Examination (APACHE) II score may have benefited more from the surgical intervention than from a drainage-first strategy. Another retrospective investigation revealed that patients who have a minimally invasive technique prior to surgical debridement are more acutely ill, and their postoperative morbidity is much higher when they are "stepped-up" to open pancreatic debridement.[6] These findings indicate that a one-size-fits-all approach to managing severe AP might lead to adverse outcomes. It is essential to acknowledge that a "step-jump," surgery-first approach may benefit some patients with NP who are refractory to PCD.[7] Unfortunately, because relatively few

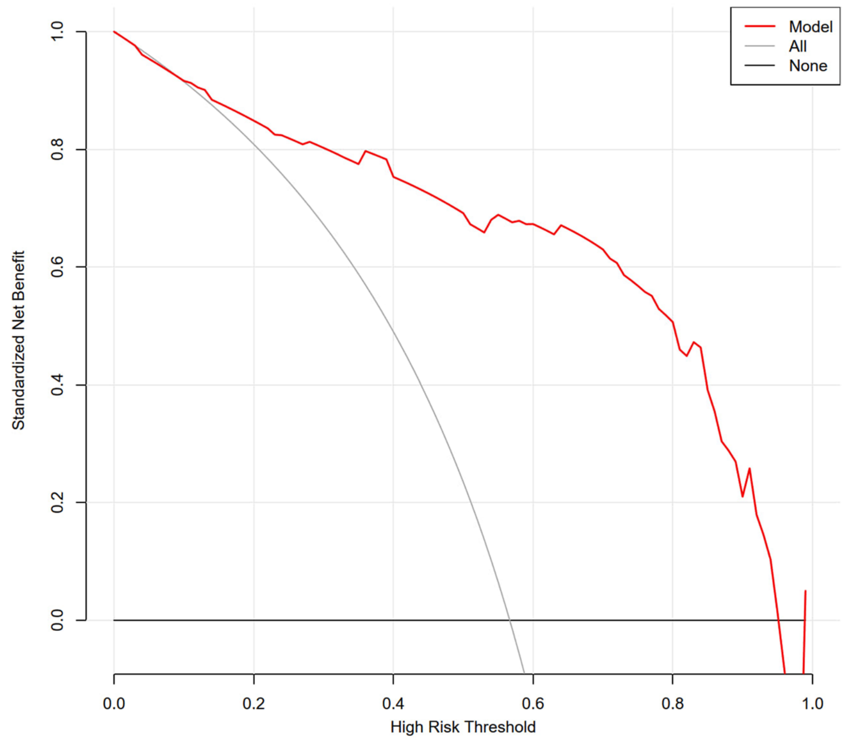

Fig. 4 Decision curve analysis (DCA) to predict the need for surgical necrosectomy in our cohort. Solid black line, net benefit when no one is at risk for surgery; gray line, net benefit when all are at risk for surgery; red line, the prediction model. The y-axis and x-axis represent net benefit and threshold probability, respectively. The DCA showed that if the threshold probability is between 0.1 and 0.95, using the model in the current study to predict the need for surgical necrosectomy adds more benefits

people with NP are treated by most centers, and because of the heterogeneity of the volume of necrosis, its anatomic distribution, and the overall physiologic state of the patients, it would be extremely difficult and probably impossible to choose these patients using a prospective trial.

In this cohort of 143 patients undergoing PCD for INP, the following characteristics were associated with the need for surgical necrosectomy: organ failure, an increasing percentage of pancreatic necrosis, extrapancreatic necrosis volume, and mean CT density of extrapancreatic necrosis. The predictive model demonstrated reasonably good discrimination and calibration. Based on the above four risk factors, we established a simple scoring system to predict the necessity of surgical necrosectomy. To our knowledge, this is the first study to develop a scoring tool to predict the need for surgery. Using the score prediction model in this study, the likelihood that the patient would eventually require surgical intervention was at least 80% when the total score exceeded or equaled 4.

Extensive pancreatic necrosis has been shown to correlate with organ failure and increased risk of mortality.[15] In a prospective analysis of 70 patients with severe AP, Babu et al.[16] determined that necrosis extent larger than fifty percent in the pancreas may not be predictive of the need for surgery in the early stages of this disease. However, Liu et al.[17] noted that the maximal amount of pancreatic necrosis greater than thirty percent was likewise associated with an increased likelihood of necrosectomy. In their post hoc study of 130

Table 3 Scoring tool based on the model and corresponding predicted probability of the need for surgical necrosectomy

Total score	Patients (*N*=143)	Patients undergoing surgical necrosectomy (*N*=81)	Predicted probability (95% CI)
0	11	1	0.033 (0.033–0.033)
1	22	3	0.130 (0.126–0.135)
2	24	6	0.271 (0.248–0.297)
3	15	6	0.548 (0.528–0.569)
4	31	27	0.800 (0.782–0.818)
5	22	21	0.923 (0.915–0.930)
6	10	9	0.977 (0.973–0.980)
7	4	4	0.990 (0.989–0.990)
8	4	4	0.996 (0.996–0.996)

CI confidence interval

prospectively included patients, Hollemans et al.[18] discovered that a pancreatic necrosis percentage of greater than fifty percent negatively impacted catheter drainage success. Not unexpectedly, the current investigation also revealed that the maximum extent of pancreatic necrosis was independently related to the requirement for surgical treatment. When the percentage of pancreatic necrosis was between 30 and 50 percent, a score of 1 was assigned; when it exceeded 50 percent, a score of 2 was assigned.

Additionally, the composition of the necrotic material may be crucial to the eventual need for surgical intervention. It is generally believed that well-encapsulated collections with homogenous or predominantly liquid contents are more amenable to PCD.[7] However, PCD itself is limited in its ability to treat solid or semi-solid necrotic tissues. A retrospective study performed by Ding et al.[19] showed more solid necrotic debris on endoscopic ultrasound (EUS) is related to more necrosectomy sessions, higher incidence of stent occlusion, and longer hospitalization. According to the findings of Hollemans et al.[18] heterogeneity of peripancreatic necrotic tissue was a risk factor for PCD failure. Ji et al. explored a mean CT density to quantify the heterogeneity of the necrotic collection. In this study, a mean CT density (in Hounsfield units, HU) of more than 20 had a sensitivity of 68.2% and a specificity of 68.1% in predicting necrosectomy need.[20] Similar results have been published previously[21]: patients in the PCD alone group had a lower mean CT density of necrotic fluid collection than those in the PCD failure group (20/35 vs. 5/16, P=0.04). A multivariate analysis of the relevant predictors revealed that the mean CT density of necrotic fluid collection is a significant predictor of surgery (OR, 1.63; 95% CI, 1.04–2.94; P=0.006). In the present study, multivariate analyses identified that a mean CT density value greater than 25 HU of necrotic fluid collection is an independent risk factor contributing to PCD failure (OR, 8.4; 95% CI 3.1–22.9; P<0.001). Consequently, we assigned this variable a score of 2 in our final score prediction model. There is a theory that higher CT densities indicate a greater proportion of solid in the necrotic fluid collection, which may obstruct the drainage tube. PCD, therefore, will not reduce necrotic fluid accumulation in such cases.

The relationship between PCD failure and increased levels of extrapancreatic necrosis remains to be established. In recent years, cohort studies have shown that extrapancreatic necrosis volume was positively correlated with complications, mortality, and organ failure.[10,22] Unexpectedly, Cao et al.[23] and Bellam et al.[24] found that extrapancreatic necrotic volume was not an independent risk factor for PCD failure after multivariate analysis, even though univariate analyses were statistically significant. In the present study, extrapancreatic necrosis was categorized into three groups: (1) < 500ml; (2) 500–999ml; and (3) ≥ 1000ml. We identified a positive link between extrapancreatic necrotic volume and PCD failure; the corresponding OR values were 4.7 (500–999ml) and 8.6 (≥ 1000ml) and were statistically significant. This inconsistency may be due to a variety of factors, including the different sample sizes, the cut-offs for grouping, and the indications used for intermediate surgical debridement. Theoretically, the larger the volume of the extrapancreatic necrotic material, the more solid or semi-solid components it may contain, and the greater the likelihood that surgical intervention will eventually be required.

The presence of organ failure may also have a significant role in determining the eventual requirement for surgical intervention. As reported by Babu et al.[16] organ failure may increase the likelihood of requiring surgical intervention. Hollemans et al.[18] concluded that only multi-organ failure is a risk factor for PCD failure. However, Tong et al.[25] found that neither single-organ nor multiple-organ failure was linked with PCD failures. Several factors may have contributed to the inconsistency in the above studies, including the different sample sizes, PCD procedures, and indications for intermediate surgical debridement used in each study. According to the revised Atlanta classification, organ failure is one of the major determinants of the severity of AP. The results of this study showed that both single-organ failure and multi-organ failure are risk factors for PCD failure, with OR values of 3.6 and 9.3, respectively, indicating that multi-organ failure is a relatively stronger predictor. This may be explained by the fact that patients with multi-organ failure tend to be more severely ill, have a higher mortality rate, and are less responsive to catheter drainage. Unlike, open necrosectomy provides a bail-out treatment option in critically ill patients who fail to improve or suffer complications after PCD.

In this study, as in most previous studies, demographic indicators, including age, gender, and laboratory indicators such as white blood cells and CRP, did not contribute to the necessity of surgical necrosectomy. It is unclear whether elevated APACHE II scores before PCD are associated with the need for subsequent surgical necrosectomy. Additionally, the APACHE II score is quite complicated since it is based on the patient's age, medical history, and 12 physiological parameters.[26] Therefore, we did not include this variable, and instead, we used the modified Marshall score, which is simple, applicable to organ dysfunctions of varying severity, and has been adopted by the revised Atlanta classification, published in 2012 and widely used today.

To our knowledge, this is the first attempt to develop an integer-based risk score to predict the necessity of surgical necrosectomy after PCD in patients with INP. Our study has several strengths. First, the risk score is based on readily available factors in daily clinical practice. The easily obtained prognostic information may help the medical team treating patients who need to undergo PCD in the communication with colleagues, patients, and their family members.

Second, the simple integer-based risk score may also aid in clinical decision-making, for instance, concerning the timing of step-up treatment toward surgical necrosectomy. Finally, a score-based prediction model can be used in risk stratification in future clinical studies, for example, when designing randomized controlled trials on primary surgical debridement in INP.

This study also has limitations. First, we performed a post hoc analysis on an existing prospective database. Although this database is unique in the number of patients and variables, predefined factors were limited by availability. Although we included some variables (e.g., imaging parameters and organ failure 24 h before the first PCD), which are known indicators of the severity of the disease, other factors not available from our database may also be of predictive value (e.g., APACHE-II score, CTSI, and other scoring systems). Moreover, some other factors of interest are dynamic variables, and the optimal extraction timing for each is still unknown; therefore, a dynamic prediction using an extended model will be warranted in the future. Second, the assessment of mean CT density is challenging from an accurate quantitative perspective. In our study, a multi-sited measurement of contrast CT density was administered because of its heterogeneous characteristic. The valid mean CT density of extrapancreatic necrosis for patients with separated lesions was equal to the maximum index of those multi-sited lesions. Further research is needed to determine how to reliably measure and compute the mean CT density of extrapancreatic necrotic tissue. Finally, even though our model has been validated internally with bootstrap resampling, it has not been validated externally. In the ideal scenario, external validation should be conducted on a similar cohort of patients with an equal or greater number.

In conclusion, this study used information from clinical assessment to estimate the necessity of surgical necrosectomy in patients with IPN being prepared for PCD treatment. A clear cluster of items consistently indicated that surgical necrosectomy was necessary: organ failure, an increasing percentage of pancreatic necrosis, and the volume and mean CT density of extrapancreatic necrosis. In this study, a simple scoring tool is developed that clinicians can use to support their clinical judgements regarding the likelihood that a patient will require surgery.

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Declarations

Conflict of Interest The authors declare no competing interests.

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