The predictive value of procalcitonin combined with C-reactive protein and D dimer in moderately severe and severe acute pancreatitis

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Objective The objective of this study is to investigate the predictive value of a parametric model constructed by using procalcitonin, C-reactive protein (CRP) and D dimer within 48 h after admission in moderately severe and severe acute pancreatitis.

Methods A total of 238 patients were enrolled, of which 170 patients were moderately severe and severe acute pancreatitis (MSAP+SAP). The concentrations of procalcitonin, CRP and D dimer within 48 h after admission were obtained. The predictive value of the parametric model, modified computed tomography severity index (MCTSI), bedside index for severity in acute pancreatitis (BISAP), Ranson score, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, modified Marshall score and systemic inflammatory response syndrome (SIRS) score of all patients was calculated and compared.

Results The area under receiver operator characteristic curve, sensitivity, specificity, Youden index and critical value of the parametric model for predicting MSAP+SAP were 0.853 (95% CI, 0.804–0.903), 84.71%, 70.59%, 55.30% and 0.2833, respectively. The sensitivity of the parametric model was higher than that of MCTSI (84.00%), Ranson score (73.53%), BISAP (56.47%), APACHE II score (27.65%), modified Marshall score (17.06%) and SIRS score (78.24%); the specificity of it were higher than that of MCTSI (52.94%) and Ranson score (67.65%), but lower than BISAP (73.53%), APACHE II score (76.47%), modified Marshall score (100%)and SIRS score (100.00%).

Conclusion The parametric model constructed by using procalcitonin 48 h, CRP 48 h and D dimer 48 h can be regarded as an evaluation model for predicting moderately severe and severe acute pancreatitis. Eur J Gastroenterol Hepatol 34: 744–750

Introduction

Acute pancreatitis is caused by various etiologies and is characterized by pathologic changes, such as edema, bleeding and necrosis of the pancreatic tissue [1]. There are 300 000 new cases of acute pancreatitis in the USA each year, of which about 10–20% are of severe pancreatitis [2]. Acute pancreatitis is one of the main causes of hospitalization in patients with gastrointestinal diseases in the USA [3,4], and its total cost is more than 2 billion dollars [5]. Patients with severe acute pancreatitis (SAP) may experience systemic inflammatory response syndrome, multiple organ failure and even death [4].

Generally, the severity of acute pancreatitis is evaluated by Acute Physiology and Chronic Health Evaluation II (APACHE II) score, Ranson score, bedside index for severity in acute pancreatitis (BISAP), modified computed tomography severity index (MCTSI), systemic inflammatory response syndrome (SIRS) score and other scoring systems. However, the above-mentioned scoring systems need a lot of serum indicators or physiologic indexes or pancreatic imaging data, which makes it inconvenient to stratify the severity of acute pancreatitis patients in the early stage. A study pointed out that only about 19% of acute pancreatitis patients had been accurately classified by severity, and only 67% of SAP patients received timely treatment in the ICU [6]. Therefore, a relatively simple and sensitive method to evaluate the severity of acute pancreatitis is of great significance for the clinical diagnosis and treatment of acute pancreatitis.

Acute pancreatitis may comprise the interaction between the inflammatory response system and the coagulation system [7]. It is prevalent to evaluate the severity of acute pancreatitis by using inflammatory and coagulation indicators. A single indicator, such as procalcitonin, C-reactive protein (CRP) and D dimer has been proved to be useful to predict SAP.

Among previous studies, few studies combined procalcitonin, CRP and D dimer to predict the severity of acute pancreatitis. The value of the combination of procalcitonin, CRP and D dimer to predict the severity of acute pancreatitis needs more supporting evidence. Based on the background, this study was conducted for analyzing the

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predictive value of the maximum concentrations of these three indicators within 48 h after admission for moderately severe acute pancreatitis (MSAP) and SAP. The parametric model constructed by using procalcitonin 48 h, CRP 48 h and D dimer 48 h, and the other scoring systems of acute pancreatitis were compared.

Materials and methods

Patients and classification

Based on an electronic medical record database, a total of 238 patients with acute pancreatitis, who were hospitalized at the First Affiliated Hospital of Fujian Medical University for the first time between 1 January 2015 and 30 June 2020 were reviewed in this study.

According to the revised Atlanta Classification [2], a diagnosis of acute pancreatitis requires two of the following three features: (1) abdominal pain consistent with acute pancreatitis (acute onset of a persistent, severe, epigastric pain often radiating to the back); (2) serum lipase activity (or amylase activity) at least three times greater than the upper limit of normal and (3) characteristic findings of acute pancreatitis on contrast-enhanced computed tomography, MRI or transabdominal ultrasonography.

Acute pancreatitis severity was classified into three classes. Mild acute pancreatitis (MAP) patients did not have accompanying organ failure and local or systemic complications, Ranson score <3, APACHE II score <8, BISAP <3 and MCTSI <4. MSAP was characterized by the presence of transient organ failure (less than 48 h) or local or systemic complications, Ranson score ≥3, APACHE II score ≥8, BISAP ≥3 and MCTSI score ≥4. SAP was defined as persistent organ failure for more than 48 h. The diagnosis of organ failure was based on a modified Marshall score, and a score of 2 or more was considered to be the presence.

Measures in SIRS diagnostic criteria [8]: (1) temperature >38 °C or <36 °C; (2) heart rate >90 beats/min; (3) respiratory rate >20 breaths/min or $PaCO_2$ <32 mm Hg; (4) white blood cell count >12 000 cells/mm^3, <4,000 cells/mm^3 or > 10% immature (band) forms. SIRS was defined as the presence of 2 or more SIRS criteria.

Patients with any of the following features were excluded: (1) acute recurrence of chronic pancreatitis; (2) acute perforation of peptic ulcer; (3) acute intestinal obstruction; (4) acute gastroenteritis; (5) acute myocardial infarction; (6) malignant pancreatic tumor; (7) patients under 18 years; (8) pregnant or lactating patients and (9) patients who gave up treatment.

The infection of the organ was diagnosed by positive etiological examination, including blood, sputum and urine samples.

Data collection

The maximum serum concentrations of procalcitonin, CRP and D dimer within 48 h after admission and general clinical data were collected. The parametric model was constructed by using procalcitonin 48 h, CRP 48 h and D dimer 48 h.

Treatment methods

All patients were given conventional treatment, including fasting, gastrointestinal decompression, antacid therapy, fluid resuscitation, maintenance of water and electrolyte and acid base balance and antibiotics when necessary.

Statistics

SPSS 22.0 (IBM Corp, Armonk, USA) was used for statistical analysis. Normally distributed data were presented as mean with mean ± SD (x ± SD). Comparison between variables was performed using the *t*-test. Non-normally distributed data were presented as median [interquartile range (IQR)]. The Wilcoxon rank-sum test was used for the comparison of continuous variables. Categorical variables were expressed as absolute numbers and percentages. For the association between two variables, Pearson's chi-square test or Spearman rank correlation test was applied, as appropriate. The receiver operator characteristic (ROC) curve was produced. The area under the ROC curve (AUC) was used to assess the predictive accuracy of various indicators and to determine the optimum cut-off points with optimal sensitivity and specificity. The AUC was calculated using a 95% confidence interval (CI). P value < 0.05 was considered statistically significant.

Ethics statement

The study obtained approval from the ethics committee of the First Affiliated Hospital of Fujian Medical University.

Results

Baseline data

A total of 238 patients with acute pancreatitis were enrolled in the study. Furthermore, 68 patients were divided into the MAP group, and 170 patients were divided into the MSAP+SAP group (MSAP 158 cases, SAP 12 cases). There was no significant difference in sex ($P > 0.05$). There was a significant difference in age, etiology, blood purification treatment, hospitalization days and expenses ($P < 0.05$) (Table 1).

There was a significant difference between the two groups in procalcitonin 48 h, CRP 48 h, D dimer 48 h, serum lactate dehydrogenase, white blood cell count, blood glucose, blood urea nitrogen, triglyceride, albumin and serum calcium ($P < 0.05$) (Table 2).

Correlation analysis

Bivariate correlation analysis showed that procalcitonin 48 h was positively correlated with acute pancreatitis severity, Ranson score, APACHE II score, BISAP, modified Marshall score *and SIRS score* ($r > 0$; $P < 0.05$). CRP 48 h was positively correlated with acute pancreatitis severity, MCTSI, Ranson score *and SIRS score* ($r > 0$; $P < 0.05$). D dimer 48h was positively correlated with acute pancreatitis severity, MCTSI, Ranson score, APACHE II score, BISAP, modified Marshall score *and SIRS score* ($r > 0$; $P < 0.05$) (Table 3).

Diagnostic value

The ROC curves of procalcitonin 48 h, CRP 48 h and D dimer 48 h for diagnosing MSAP+SAP were plotted. The

AUC, cut-off point, sensitivity, specificity and Youden index of procalcitonin 48 h were 0.795, 0.255 ng/mL, 78.20%, 69.10% and 47.30%, respectively; the corresponding values of CRP 48 h were 0.768, 84.340 mg/L, 72.90%, 80.90% and 53.80% respectively; and the corresponding values of D dimer 48 h were 0.789, 1.805 mg/L, 74.70%, 75.00% and 49.70%, respectively.

Using procalcitonin 48 h, CRP 48 h, and D dimer 48 h as independent variables, a logistic regression model was obtained: Logit (P) = −1.52 + 0.89* procalcitonin 48 h + 0.014* CRP 48 h + 0.327* D dimer 48 h. The AUC, sensitivity, specificity and Youden index of parametric model for diagnosing MSAP+SAP were 0.853, 84.71%, 70.59% and 55.30%, respectively (Table 4 and Fig. 1).

Table 1. Demographic characteristics and clinical findings

Variables	MAP (*n* = 68)	MSAP+SAP (*n* = 170)	*P* value
Male (%)	35 (51.50)	102 (60.00)	0.229
Age (years)	58.04 ± 15.93	51.44 ± 16.63	0.005
Etiology (%)			
Biliary	51 (75.00)	83 (48.80)	0.001
Hyperlipidemic	7 (10.20)	57 (33.50)	
Alcoholic	5 (7.40)	10 (5.90)	
Other	5 (7.40)	20 (11.80)	
Local complication (%)			
PPC	0	19 (11.18)	
APFC	0	85 (50.00)	
WON	0	2 (1.18)	
PVT	0	2 (1.18)	
Systemic complication (%)			
SIRS	0	133 (78.24)	
Acute renal failure	0	16 (9.41)	
Acute respiratory failure	0	8 (4.71)	
Other (%)			
Infection	2 (2.94)	0	
Mechanical ventilation	0	8 (4.71)	
Blood purification	2 (2.94)	50 (29.41)	<0.001
Length of stay (days)	8 (7–11)	12 (9–16)	<0.001
Total expense (¥)	14743.25 (10982.57–22350.03)	26132.47 (18303.10–41348.69)	<0.001

APFC, acute peripancreatic fluid collection; MAP, mild acute pancreatitis; MSAP, moderately severe acute pancreatitis; PPC, Pancreatic pseudocyst; PVT, portal vein thrombosis; SAP, severe acute pancreatitis; SIRS, systemic inflammatory response syndrome;WON, walled-off necrosis.

Risk in predicting moderately severe acute pancreatitis+severe acute pancreatitis

According to the cut-off value, procalcitonin 48 h, CRP 48 h, D dimer 48 h, and parametric model were transformed into binary classification, and the binary logistic regression model for predicting MSAP+SAP was constructed. The dependent variable Y represented the severity of acute pancreatitis. The independent variables X1, X2, X3 and X4 represented the values of procalcitonin 48 h, CRP 48 h, D dimer 48 h and parametric model, respectively (Table 5).

The results showed that the risk of predicting MSAP+SAP by using parametric model was higher than that by using procalcitonin 48 h, CRP 48 h or D dimer 48 h (OR, 13.292 vs. 8.045, 11.405, 8.860) (Table 6).

Comparison of the predictive value of parametric model and severity scoring systems

The ROC curves of parametric model, MCTSI, Ranson score, APACHE II score, BISAP and modified Marshall score for diagnosing MSAP+SAP were plotted. The AUC, sensitivity, specificity and Youden index of parametric model were 0.853, 84.71%, 70.59% and 55.30%, respectively; the corresponding values of MCTSI were 0.798, 84.00%, 52.94% and 43.50%, respectively; the corresponding values of BISAP were 0.712, 56.47%, 73.53% and 30.00%, respectively; the corresponding values of Ranson score were 0.777, 73.53%, 67.65% and 41.18% respectively; the corresponding values of APACHE II score were 0.535, 27.65%, 76.47% and 4.10%, respectively; and the corresponding values of modified Marshall score were 0.654, 17.06%, 100.00%, and 17.10% respectively; the corresponding values of SIRS score were 0.916, 78.24%, 100% and 78.24% (Table 7 and Fig. 2).

Discussion

In this study, we assessed the predictive value of a simple parametric model for MSAP+SAP, which was constructed by using procalcitonin 48 h, CRP 48 h and D dimer 48 h. The results showed that the parametric model could distinguish MSAP+SAP from MAP. While separately detecting,

Table 2. Parameters in the mild acute pancreatitis and moderately severe acute pancreatitis+severe acute pancreatitis group

Variables	MAP (*n* = 68)	MSAP+SAP (*n* = 170)	*P* value
Procalcitonin 48 h (ng/mL)	0.15 (0.05–0.36)	0.73 (0.30–4.05)	<0.001
CRP 48 h(mg/L)	51.67 (13.00–78.95)	90.00 (80.05–90.00)	<0.001
D dimer 48 h(mg/L)	1.16 (0.72–1.95)	2.88 (1.77–5.04)	<0.001
Serum amylase (U/L)	1069.50 (326.50–2135.75)	698.50 (297.00–1501.25)	0.138
Serum lipase (U/L)	2000.00 (281.25–2000.00)	2000.00 (582.75–2000.00)	0.935
AST (U/L)	46.50 (24.00–217.50)	45.00 (23.00–199.50)	0.741
LDH (U/L)	271.50 (190.75–512.00)	546.50 (332.50–897.25)	<0.001
WBC (10^9/L)	10.52 (8.62–12.41)	13.82 (11.44–17.43)	<0.001
HCT(%)	39.92 ± 4.78	41.06 ± 6.32	0.184
Blood glucose(mmol/L)	7.53 (6.10–9.07)	8.90 (7.12–12.04)	<0.001
BUN (mmol/L)	4.03 (2.90–4.96)	4.30 (3.17–6.73)	0.009
SCr (mmol/L)	61.20 (47.18–73.75)	64.90 (49.00–84.20)	0.065
Total cholesterol (mmol/L)	4.34 (3.42–5.49)	4.55 (3.41–7.68)	0.136
Triglyceride (mmol/L)	1.05 (0.74–1.75)	1.88 (1.00–10.42)	<0.001
Serum calcium (mmol/L)	2.13 (2.00–2.18)	1.99 (1.88–2.13)	<0.001
Albumin (g/L)	36.60 ± 4.42	34.49 ± 5.12	0.003

Procalcitonin 48 h: maximum concentrations of procalcitonin within 48 h after admission; CRP 48 h: maximum concentrations of CRP within 48 h after admission; DD 48 h: maximum concentrations of D dimer within 48 h after admission.
AST, aspartate aminotransferase; BUN, blood urea nitrogen; CRP, C-reactive protein; HCT: hematocrit; LDH, serum lactate dehydrogenase; MAP, mild acute pancreatitis; MSAP, moderately severe acute pancreatitis; SAP, severe acute pancreatitis; SCr, serum creatinine; WBC, white blood cell count.

Table 3. Correlation between procalcitonin 48 h, C-reactive protein 48 h, D dimer 48 h and severity scoring systems

R	AP severity	MCTSI	Ranson	BISAP	APACHE II	Modified Marshall	SIRS
(*P*)			Score		Score	Score	Score
Procalcitonin 48 h	0.462 (<0.001)[a]	0.123 (0.058)	0.305 (<0.001)	0.292 (<0.001)	0.255 (<0.001)	0.220 (0.001)	0.423 (< 0.010)[a]
CRP 48 h	0.434 (<0.001)[a]	0.322 (<0.001)	0.172 (0.008)	0.106 (0.102)	–0.041 (0.530)	0.003 (0.969)	0.287 (< 0.001)
D dimer 48 h	0.452 (<0.001)[a]	0.366 (<0.001)	0.306 (<0.001)	0.365 (<0.001)	0.142 (0.029)	0.199 (0.002)	0.409 (< 0.010)[a]

PCT 48 h: maximum concentrations of procalcitonin within 48 h after admission; CRP 48 h: maximum concentrations of CRP within 48 h after admission; D dimer 48 h: maximum concentrations of D dimer within 48 h after admission.
AP, acute pancreatitis; APACHE II score, acute physiology and chronic health Evaluation II score; BISAP, bedside index for severity in acute pancreatitis; CRP, C-reactive protein; MCTSI, modified computed tomography severity index; r: coefficient of correlation; SIRS, systemic inflammatory response syndrome.
[a]Spearman rank correlation test.

Table 4. Diagnostic value of procalcitonin 48 h, CRP 48 h and D dimer 48 h in moderately severe acute pancreatitis+severe acute pancreatitis

Variables	Cut-off	Sensitivity	Specificity	Youden Index	AUC	95% CI	*P*
		(%)	(%)	(%)			
Procalcitonin 48 h	0.255	78.20	69.10	47.30	0.795	0.735–0.855	0.000
CRP 48 h	84.340	72.90	80.90	53.80	0.768	0.698–0.837	0.000
D dimer 48 h	1.805	74.70	75.00	49.70	0.789	0.726–0.852	0.000
Parametric model	0.2833	84.71	70.59	55.30	0.853	0.804–0.903	0.000

Procalcitonin 48 h: maximum concentrations of procalcitonin within 48 h after admission; CRP 48 h: maximum concentrations of CRP within 48 h after admission; DD 48 h: maximum concentrations of D dimer within 48 h after admission; parametric model: constructed by using PCT 48 h, CRP 48 h and D dimer 48 h.
AUC, area under the ROC curve; CI, confidence interval; CRP,C-reactive protein.

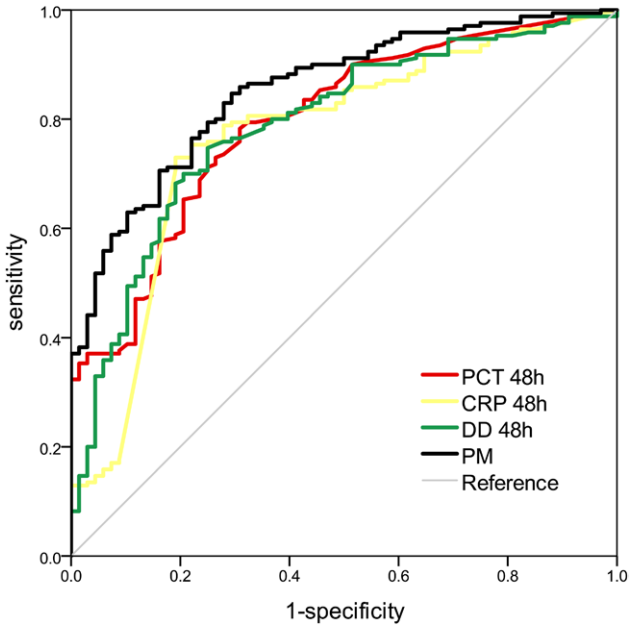

Fig. 1. Receiver operator characteristic (ROC) curves of procalcitonin 48 h, CRP 48 h, D dimer 48 h and parametric model for diagnosing MSAP+SAP. CRP, C-reactive protein; MSAP, moderately severe acute pancreatitis; PCT, procalcitonin; PM, parametric model; SAP, severe acute pancreatitis.

Table 5. The assignment of procalcitonin 48 h, C-reactive protein 48 h, D dimer 48 h, parametric model, and moderately severe acute pancreatitis+severe acute pancreatitis

Y	X1	X2	X3	X4
1	1	1	1	1
0	0	0	1	0
1	1	0	1	1
…	…	…	…	…

(1) Y: stands for the severity of AP; 1 = MSAP+SAP, 0 = MAP.
(2) X1~X4: stand for the value of procalcitonin 48 h, CRP 48 h, D dimer 48 h and parametric model, respectively; 1 = higher than the cut-off value and 0 = lower than the cut-off value.

Table 6. The risk of procalcitonin 48 h, CRP 48 h, D dimer 48 h and parametric model for predicting moderately severe acute pancreatitis+severe acute pancreatitis

Variables	Cutoff	OR	95% CI	*P* value
Procalcitonin 48 h	0.255	8.045	4.283–15.111	0.000
CRP 48 h	84.340	11.405	5.705–22.799	0.000
D dimer 48 h	1.805	8.860	4.630–16.951	0.000
Parametric model	0.2833	13.292	6.814–25.930	0.000

Procalcitonin 48 h: maximum concentrations of procalcitonin within 48 h after admission; CRP 48 h: maximum concentrations of CRP within 48 h after admission; DD 48 h: maximum concentrations of D dimer within 48 h after admission; parametric model: constructed by using procalcitonin 48 h, CRP 48 h, and D dimer 48 h.
CI, confidence interval; CRP,C-reactive protein; OR, odds ratio.

the AUC values of procalcitonin 48 h, CRP 48 h and D dimer 48 h for predicting MSAP+SAP were 0.795, 0.768 and 0.789, respectively, and the sensitivity values of the respective indicators were 78.20%, 72.90% and 74.70%, respectively. Interestingly, our study suggested that joint detection of the three indicators had a better predictive value, and the sensitivity, AUC and Youden index were further improved. Moreover, the parametric model had a higher risk ratio for predicting MSAP+SAP than single indicators (13.292 vs. 8.045, 11.405, 8.860).

Generally, procalcitonin was used to assess infection, which reached the peak at about 24 h. However, it has been confirmed to be useful to predict SAP. Our results showed that the sensitivity and specificity of procalcitonin 48 h for predicting MSAP+SAP were 78.20 and 69.10%, respectively, which were consistent with those in a previous study [9]. When combined with infection, the severity of acute pancreatitis will be further aggravated. Especially, the biliary tract or extra-pancreatic infection often occurs in biliary acute pancreatitis. Unfortunately, the positive rate of etiological tests is low, which is not convenient to judge and intervene acute pancreatitis with infection. According to a study, only 440 of the 2829 blood culture cases were positive [10]. Luckily, procalcitonin is sensitive to identify bacterial infection [11], and it is considered an early marker of systemic bacterial infection and sepsis [12]. Therefore, procalcitonin can be a critical auxiliary indicator to classify the severity of acute pancreatitis, especially

Table 7. The predictive value of parametric model and severity scoring systems for moderately severe acute pancreatitis+severe acute pancreatitis

Assessment	Cut-off	Sensitivity	Specificity	Youden Index	AUC	95% CI	*P*
Models		(%)	(%)	(%)			
Parametric model	0.2833	84.71	70.59	55.30	0.853	0.804–0.903	0.000
MCTSI	4	84.00	52.94	43.50	0.798	0.742–0.854	0.000
BISAP	3	56.47	73.53	30.00	0.712	0.641–0.783	0.000
Ranson score	3	73.53	67.65	41.18	0.777	0.714–0.840	0.000
APACHE II score	8	27.65	76.47	4.10	0.535	0.457–0.613	0.399
Modified Marshall score	2	17.06	100.00	17.10	0.654	0.583–0.724	0.000
SIRS score	2	78.24	100.00	78.24	0.916	0.882–0.951	0.000

parametric model: constructed by using procalcitonin 48 h, CRP 48 h, and D dimer 48 h.
APACHE II score, acute physiology and chronic health Evaluation II score; AUC, area under the ROC curve; BISAP, bedside index for severity in acute pancreatitis; CI, confidence interval; MCTSI, modified computed tomography severity index; SIRS, systemic inflammatory response syndrome.

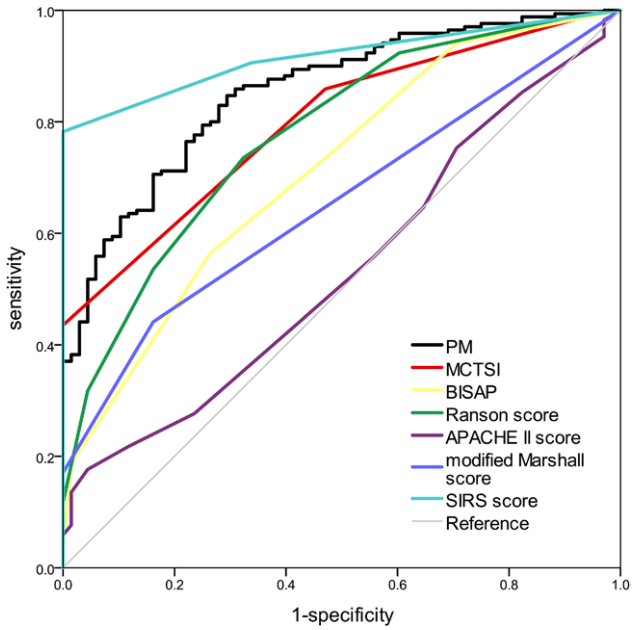

Fig. 2. Receiver operator characteristic (ROC) curves of parametric model and severity scoring systems for diagnosing MSAP+SAP. APACHE II, Acute Physiology and Chronic Health Evaluation II score; BISAP, bedside index for severity in acute pancreatitis; MSAP, moderately severe acute pancreatitis; MCTSI, modified computed tomography severity index; SAP, severe acute pancreatitis; SIRS, systemic inflammatory response syndrome.

the risk of acute pancreatitis combined with infection. However, the number of co-infected patients was only two, they had combined *Acinetobacter baumannii* infection of lungs, and they were categorized in the MAP group. Acute pancreatitis patients with pathogen-based infection were not found in the MSAP+SAP group; thus, it was not sufficient to evaluate the predictive value of procalcitonin for acute pancreatitis with infection.

CRP is a nonspecific acute-phase reactive protein and has been widely used to predict SAP [13]. It reaches the peak at about 48–72 h after onset. This study showed that the sensitivity and specificity of CRP 48 h for predicting MSAP+SAP were 72.9 and 80.9%, respectively, which were similar to those in previous studies [14,15]. The cut-off value of CRP 48 h was less than that in the previous reports, in which the cut-off of CRP was 120–160 mg/L for predicting SAP within 48 h of admission [16,17]. Stirling *et al.* [18] pointed out that when the cut-off of CRP was 90 mg/L within 48 h of admission, the specificity of CRP to predict the severity of acute pancreatitis was high (about 85.2%). However, Cardoso *et al.* [19] showed that a CRP cutoff of 60 mg/L had a negative predictive value of 100% in predicting SAP within 24 h of admission, and the risk of death and complications was decreased. In this study, there was a significant increase in CRP 48 h in the MSAP+SAP group within 48 h of admission. We could not ignore the value of CRP to predict MSAP+SAP, although it may not reach the peak. The time for CRP to reach its peak is relatively long, which limits its use as a single predictor of severity for acute pancreatitis within 48 h of admission. Therefore, the combined detection of CRP and procalcitonin within 48 h of admission can be more valuable for predicting MSAP+SAP.

D dimer is a specific product of degradation of cross-linked fibrin, which indirectly reflects the coagulation disorder. Some studies have found that D dimer is related to the severity and complications of acute pancreatitis, and patients with acute pancreatitis may develop coagulation and microcirculation disorders in the acute phase [20,21]. Our results showed that the specificity and risk ratio of D dimer 48 h were 75.0 and 8.860, respectively, for predicting MSAP+SAP. A study showed that the risk ratio of D dimer for predicting SAP was 4.504 in all acute pancreatitis cases, and there was a higher risk ratio for hyperlipidemic acute pancreatitis (OR = 9.824) [22]. Previous studies have shown that the ranges of sensitivity and specificity of D dimer for predicting SAP were 86.5–92.6% and 75.6–77.69%, respectively [22]. In addition, this study suggested that D dimer 48 h was positively correlated with the severity of acute pancreatitis, and MCTSI, BISAP, Ranson score, APACHE II score and Marshall score. Wu *et al.* [23] found that the D dimer level was positively correlated with the Ranson score and pancreatic CT grade. Additionally, a study of over 2000 samples [24] indicated that elevated D dimer levels were independently associated with pancreatitis prognosis and complications. The risk of death in acute pancreatitis patients with a median D dimer level of 0.4–0.8 mg/L was 11.2 times higher than that in patients with a median D dimer level of 0.2–0.4 mg/L at admission [25]. These results suggest that D dimer is useful for predicting the severity, complications and prognosis of acute pancreatitis.

More importantly, our results showed that the sensitivity, Youden index and AUC of the parametric model were higher than those of MCTSI, BISAP, Ranson score, APACHE II score and modified Marshall score. Not only did it reflect the body state at the onset of acute pancreatitis from the three aspects of inflammation, infection, and blood coagulation, but it also merely required three serum indicators.

Among the scoring systems for the severity of acute pancreatitis, the Ranson score is complicated and requires multiple serum indicators of two-time points at admission and within 48 h after admission. In our study, the sensitivity and specificity of the Ranson score for predicting MSAP+SAP were 73.53 and 67.65%, respectively. The reports showed that the Ranson score predicted SAP with a sensitivity of 47–91.67% and a specificity of 44.3–96.15% [26–28]. BISAP requires general signs, blood gas analysis results and chest imaging data, but the examination rate of chest imaging is low after the onset of acute pancreatitis [29]. In our study, the sensitivity and specificity of MSAP+SAP predicted by BISAP were 56.47 and 73.53%, respectively, which is similar to the reports showing that the sensitivity and specificity of BISAP for predicting SAP were 61.9–79.17% and 72.1–88.46%, respectively [27,30].

MCTSI is an imaging scoring system, which has intuitive advantages in the evaluation of pancreatic edema and necrosis. The sensitivity, specificity and AUC of the reported MCTSI for predicting SAP were 35–66.7%, 67.1–95% and 0.652, respectively [26,27,30]. This study showed that MCTSI had a high sensitivity for predicting MSAP+SAP. However, the specificity of the MCTSI score was low in this study, suggesting that the combination of MCTSI and other scoring systems may have complementary advantages. In addition, combining this parametric model with pancreatic, thoracic and abdominal imaging data may be more helpful for the diagnosis of MSAP and SAP in clinical practice.

Generally, the cutoff value of the APACHE II score for predicting SAP is 8 points. Its sensitivity and specificity were 58–81% and 65.7–90%, respectively [31,32]. In this study, the specificity and sensitivity of MSAP+SAP were 76.47 and 21.8%, respectively. The sensitivity was lower than that reported in related studies, which may be due to the few SAP cases (only 12 cases). In addition, the cutoff of 8 points of APACHE II score may be very high for most patients in the MSAP group, which has been pointed out in a previous study [33]. It is well known that the APACHE II score is not a scoring system designed specifically for acute pancreatitis. Although it has a high predictive value for SAP with multiple organ failure, the predictive value for MAP or MSAP was low.

The modified Marshall score is originally used to predict organ failure, and a score of ≥2 indicates organ failure. It was also used to predict SAP, some studies have reported that its sensitivity, specificity and AUC were 83.33%, 87.5% and 0.938, respectively [28]. In this study, the sensitivity of the modified Marshall score for predicting MSAP+SAP was only 17.1%, and its specificity was 100%, which may be related to the small number of patients with multiple organ failure in the MSAP+MAP group. However, it could still establish a diagnosis for excluding multiple organ failure because of its high specificity.

SIRS score was used to predict SAP because of the high sensitivity and negative predictive value of persistent SIRS in predicting persistent organ failure and mortality [34–36]. The sensitivity, specificity and AUC of it for predicting SAP were 80.6–85.0%, 48.3–65.9% and 0.73 [37,38], respectively. Our results showed the lower sensitivity and the higher specificity and AUC of SIRS than previous studies, due to the absence of SIRS in the MAP group. Although the AUC of parametric model was inferior to the SIRS score, it was superior to other predictive scoring systems. The parametric model still highlighted the merit of predictive predisposition for MSAP and SAP in the early stage.

The limitations of this study include the following three aspects: First, the study was a retrospective and single-center, and only patients with first-onset of acute pancreatitis were included. Second, only the data of CRP, procalcitoni, and D dimer within 48 h after admission were collected, and further longer dynamic observation was not conducted. Finally, age may have an influence on the basal value of CRP and D dimer before the onset of acute pancreatitis. The influence of age on the elevation of CRP and D dimer during acute pancreatitis development needs further study.

In conclusion, this study showed that the parametric model constructed by using procalcitonin 48 h, CRP 48 h and D dimer 48 h can be regarded as an evaluation model for predicting the severity of MSAP+SAP.

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Conflicts of interest

There are no conflicts of interest.

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