Acute pancreatitis is one of the leading gastrointestinal disorders that require urgent clinical treatment and increase globally in recent years [1, 2, 3]. The most common cause of AP was gallstones and alcohol consumption, hypertriglyceridemia, obesity, diabetes, smoking, drugs, endoscopic retrograde cholangiopancreatography (ERCP), trauma, and infection are also well-known suspected risk factors of pancreatitis [4, 5, 6, 7, 8, 9]. It represents a disease characterized by symptoms such as severe abdominal pain, nausea, and vomiting, which is due to the activation of various digestive enzymes [10, 11]. The clinical course of acute pancreatitis is variable, ranging from local pancreatic inflammation to consequently systemic inflammatory response, which is divided into mild acute pancreatitis (MAP), moderately severe acute pancreatitis (MSAP), and severe acute pancreatitis (SAP). Infected pancreatic necrosis and/or sepsis are major complications contributing to death at any stage [12, 13, 14, 15]. Most acute pancreatitis patients experience mild courses with early oral feeding result in rapid clinical recovery [16]. Nearly about 30% of patients may progress onto severe forms named hemorrhagic necrotizing pancreatitis or SAP, which would lead to systemic inflammatory response syndrome (SIRS), and even multiple organ dysfunction syndromes with poor prognosis [17, 18, 19, 20]. Therefore, early diagnosis and timely treatment are critical to guide fluid resuscitation and initiate high-dependency or intensive care treatment and reduce morbidity and mortality of SAP. Early and accurate evaluation of AP severity is important to prevent progression and clinical outcomes [21, 22, 23].

With the improvement of people’s living standards and the change in dietary habits, overweight and obese people have increased across the globe in recent years. Obesity is measured by body mass index (BMI, kg/m²), and is considered an established risk factor for type 2 diabetes, hyperlipidemia, and gallstone, which are all risk factors for pancreatitis [24, 25, 26, 27]. It has likely contributed to increasing the incidence and severity of acute pancreatitis [28, 29, 30, 31]. In addition, high BMI has also been directly associated with an increased risk of acute pancreatitis in some prospective studies [32]. Moreover, obese patients have a higher risk of severe acute pancreatitis. Currently, there is no uniform standard for the diagnosis of obesity all over the world, and we have adjusted the obesity judgment criteria based on BMI in China by the Chinese Society for Metabolic & Bariatric Surgery (CSMBS), which makes it more suitable.
for Chinese conditions. According to the latest criteria, Chinese adults define a BMI in the range of $18.5 \leq \text{BMI} < 24.9 \text{kg/m}^2$ as normal weight, $25.0 \leq \text{BMI} < 27.5 \text{kg/m}^2$ as overweight, and $\text{BMI} \geq 27.5 \text{kg/m}^2$ as obese [33, 34, 35]. Because of various definitions of BMI standards for obesity at home and abroad, this study is based on the most recent BMI standards in China to explore the judgment value of BMI and related clinical examinations in the evaluation of the early condition of acute pancreatitis. Since obesity and biliary diseases especially biliary stones are important factors causing pancreatitis, this study aimed to evaluate the clinical significance of BMI in the early assessment of the severity of acute biliary pancreatitis.

1. Methods

1.1. Patient selection

This study retrospectively included ABP cases who were admitted to Beijing Jishuitan Hospital from January 1, 2019, to December 31, 2021. The clinical features data analyzed in the study included general information such as sex, age, body mass index (BMI), history, and vital signs when admitted. Meanwhile, laboratory results, imaging tests, treatments, complications, and hospital stays. This study was approved by the Ethics Committee of the Beijing Jishuitan Hospital, and informed consent was obtained from all individuals.

2. Standards of diagnosis

2.1. Diagnostic criteria for acute pancreatitis

The diagnosis and classification of the severity of AP were defined according to the 2012 revision of the Atlanta Classification [14]. The diagnosis of AP requires 2 of the following 3 features: (1) abdominal pain consistent with the disease (2) serum lipase activity (or amylase activity) at least three times greater than the upper limit of normal; and (3) characteristic findings from abdominal imaging. Disease severity was graded as mild or moderately severe, based on the presence of local or systemic complications and transient/permanent organ failure. The diagnostic criteria of acute biliary pancreatitis (ABP) were as follows: the patients were grouped under the diagnostic criteria of AP, imaging examination found gallbladder stones and/or bile duct stones, and laboratory exams showed increased levels of ALT and bilirubin [36].

2.2. Ranson score

The Ranson score was the first specific multifactorial scoring system for patients with AP published in 1974 and modified in 1979 by Ranson. It consists of 11 parameters identified as significant prognostic factors: Five parameters measured at admission and six during the next 48 h. Present on admission: (1) Age > 55 years, (2) WBC > 16000/mm³, (3) Glucose > 11.1 mmol/L, (4) LDH > 350 U/L, (5) AST > 250 U/L; During the first 48 h: (1) Hematocrit decrease > 10% points, (2) BUN increase > 1.79 mmol/L, (3) Serum calcium < 2 mmol/L, (4) PaO₂ < 60 mmHg, (5) Base deficit > 4 mmol/L, (6) Fluid sequestration > 6 L. Mortality increases with an increasing score. A score between 1 to 3 criteria represents mild AP; the mortality rate rises significantly with four or more criteria, being 100% in those with six or more [37, 38].

2.3. Modified CT severity index (MCTSI) scoring criteria

The degree of AP was also obtained by the established CT severity index (CTSI) developed by Balthazar et al. and the modified CT severity index (MCTSI) by Mortele et al [39, 40] (Table 1). For the MCTSI, the morphologic severity of pancreatitis was categorized as mild (0–2 points), moderate (4–6 points), or severe (8–10 points). The MCTSI was easy to calculate, and more accurately to judge the severity of infection, organ failure, the length of hospital stays, and death [41, 42, 43]. Each score was applied independently to the investigated CT studies by both observers, who were blinded to all clinical parameters and the scoring results of their counterparts.

2.4. Statistical analysis

The categorical variables are presented as numbers and continuous variables are presented as medians and mean differences. The categorical variables were statistically compared by the chi-square test. The Mann-Whitney U-test and t-test were used for continuous variables and measurement data. The logistic regression model was used to determine the independent factors for variables with significance in the univariate and multivariate analyses. The logistic regression was done by forward step-wise and Wald p-value. The results are expressed as odd ratios (ORs) with 95% confidence intervals (CIs). The ROC curve was used for predicting SAP sensitivity analysis. P < 0.05 was considered as the significance level. SPSS 24.0 statistical software was used for all data analysis.

3. Results

A total of 259 patients with ABP were admitted to the study. There were 138 males (53.3%) and 121 females (46.7%). The mean age was 60.98 ± 1.03 (19–97) years for all AP patients. The mean BMI of the patients was 25.97 ± 0.23 (18.79–38.67) kg/m². According to the Chinese criteria, the number of obese patients of ABP was 99 (38.2%), the overweight patients was 61 (23.6%), and the normal weight patients were 99 (38.2%). The MAP patients were 115 (44.4%), the MSAP cases were 106 (40.9%), and the SAP cases were 38 (14.7%).

Table 1. Modified CTSI (MCTSI) score.

| Characteristics               | MCTSI (0–10) |
|-------------------------------|-------------|
| Pancreatic inflammation       |             |
| Normal pancreas               | 0           |
| Focal or diffuse enlargement of pancreas | 2           |
| Pancreatic necrosis           |             |
| None                          | 0           |
| Less than 30%                 | 2           |
| Between 30% and 50%           | 4           |
| More than 50%                 | 4           |
| Extrapancreatic complications | 3           |

* One or more of pleural effusion, ascites, vascular complications, parenchymal complications, or gastrointestinal tract involvement.

| Scores | BMI (kg/m²) | 25 | 25–27.4 | ≥27.5 | p     |
|--------|-------------|----|---------|-------|-------|
| Ranson |             |    |         |       |       |
| <3     | 47 (47.5%)  | 17 (27.9%) | 23 (23.2%) | 0.000*|
| 4–6    | 40 (40.4%)  | 28 (45.9%) | 40 (40.4%) |       |
| >7     | 12 (12.1%)  | 16 (26.2%) | 36 (36.4%) |       |
| <3     | 47 (47.5%)  | 17 (27.9%) | 23 (23.2%) | 0.000*|
| ≥3     | 52 (52.5%)  | 44 (72.1%) | 76 (76.8%) |       |
| MCTSI  |             |    |         |       |       |
| <3     | 54 (54.5%)  | 27 (44.3%) | 26 (26.3%) | 0.000*|
| 4–6    | 40 (40.4%)  | 23 (37.7%) | 55 (55.6%) |       |
| ≥7     | 5 (5.1%)    | 11 (18.0%) | 18 (18.2%) |       |
| <3     | 54 (54.5%)  | 27 (44.3%) | 26 (26.3%) | 0.000*|
| ≥4     | 45 (45.5%)  | 34 (55.7%) | 73 (73.7%) |       |
| Variables          | Acute Biliary Pancreatitis | p      |
|--------------------|----------------------------|--------|
|                    | MAP (n = 115)              | MSAP (n = 106) | SAP (n = 38) |
| Sex                |                            |        |              |
| Male               | 58 (50.4%)                 | 60 (56.6%) | 20 (52.6%)   |
| Female             | 57 (49.6%)                 | 46 (43.4%) | 18 (47.4%)   |
| Age (years)        |                            |        |              |
| <63                | 63 (54.8%)                 | 48 (45.3%) | 16 (42.1%)   |
| ≥63                | 52 (45.2%)                 | 58 (54.7%) | 22 (57.9%)   |
| BMI (kg/m²)        |                            |        |              |
| <25.0              | 61 (53.0%)                 | 34 (32.1%) | 4 (10.5%)    |
| 25.0 ~ 27.4        | 28 (24.3%)                 | 21 (19.8%) | 12 (31.6%)   |
| ≥27.5              | 26 (22.6%)                 | 51 (48.1%) | 22 (57.9%)   |
| <27.5              | 89 (77.4%)                 | 55 (51.9%) | 16 (42.1%)   |
| ≥27.5              | 26 (22.6%)                 | 51 (48.1%) | 22 (57.9%)   |
| Ranson             |                            |        |              |
| <3                 | 78 (67.8%)                 | 9 (8.5%)  | 0 (0.0%)     |
| 3–4                | 36 (31.3%)                 | 65 (61.3%) | 7 (18.4%)    |
| >4                 | 1 (0.9%)                   | 32 (30.2%) | 31 (81.6%)   |
| ≤3                 | 78 (67.8%)                 | 9 (8.5%)  | 0 (0.0%)     |
| ≥3                 | 37 (32.2%)                 | 97 (91.5%) | 38 (100.0%)  |
| MCTSI              |                            |        |              |
| ≤3                 | 99 (86.1%)                 | 8 (7.5%)  | 0 (0.0%)     |
| 4–6                | 16 (13.9%)                 | 95 (89.6%) | 7 (18.4%)    |
| ≥7                 | 0 (0.0%)                   | 3 (2.8%)  | 31 (81.6%)   |
| ≤3                 | 99 (86.1%)                 | 8 (7.5%)  | 0 (0.0%)     |
| >3                 | 16 (13.9%)                 | 98 (92.5%) | 38 (100.0%)  |
| Recurrence         |                            |        |              |
| Yes                | 23 (20.0%)                 | 37 (34.9%) | 14 (36.8%)   |
| No                 | 92 (80.0%)                 | 69 (65.1%) | 24 (63.2%)   |
| Live               |                            |        |              |
| Yes                | 115 (100.0%)               | 106 (100.0%) | 34 (89.5%) |
| No                 | 0 (0.0%)                   | 0 (0.0%)  | 4 (10.5%)    |
| Complication       |                            |        |              |
| No                 | 51 (44.3%)                 | 24 (22.6%) | 3 (7.9%)     |
| Yes                | 64 (55.7%)                 | 82 (77.4%) | 35 (92.1%)   |
| Fatty Liver        |                            |        |              |
| No                 | 88 (76.5%)                 | 82 (77.4%) | 30 (78.9%)   |
| Yes                | 27 (23.5%)                 | 24 (22.6%) | 8 (21.1%)    |
| Stay in Hospital (Days) | 10.04 ± 0.41 | 10.81 ± 0.42 | 16.39 ± 2.29 |
| BMI (kg/m²)        | 24.80 ± 0.35               | 26.63 ± 0.37 | 27.66 ± 0.38 |
| Age (years)        | 58.83 ± 1.57               | 63.03 ± 1.62 | 61.79 ± 2.37 |
| WBC (×10³/L)       | 10.63 ± 0.34               | 13.08 ± 0.41 | 15.43 ± 0.72 |
| ALT (IU/L)         | 206.32 ± 19.65             | 249.98 ± 21.44 | 231.16 ± 37.80 |
| AST (IU/L)         | 224.84 ± 24.09             | 337.71 ± 34.95 | 332.29 ± 67.41 |
| TBIL (µmol/L)      | 44.89 ± 3.97               | 45.39 ± 3.40 | 57.90 ± 9.31 |
| DBIL (µmol/L)      | 24.81 ± 2.77               | 24.45 ± 1.84 | 35.72 ± 6.72 |
| Glucose (mmol/L)   | 8.24 ± 0.27                | 9.48 ± 0.34 | 9.56 ± 0.54  |
| UREA (mmol/L)      | 5.32 ± 0.18                | 5.92 ± 0.20 | 7.73 ± 1.00  |
| CREA (µmol/L)      | 66.94 ± 1.72               | 70.18 ± 2.13 | 91.24 ± 11.35 |
| Calcium (mmol/L)   | 2.23 ± 0.02                | 2.15 ± 0.02 | 2.00 ± 0.03  |
| TG (mmol/L)        | 1.87 ± 0.32                | 1.71 ± 0.29 | 1.69 ± 0.26  |
| CHOL (mmol/L)      | 4.74 ± 0.14                | 4.71 ± 0.26 | 4.31 ± 0.20  |
| LDH (IU/L)         | 289.12 ± 18.69             | 366.23 ± 26.55 | 468.92 ± 59.96 |
| D-dimer (µg/L)     | 2.00 ± 0.39                | 2.98 ± 0.57 | 3.72 ± 0.68  |
| Serum Amylase (U/L) | 1020.87 ± 82.59          | 1672.71 ± 119.09 | 1416.21 ± 191.63 |
| Urinary Amylase (U/L) | 6631.26 ± 982.28       | 8788.60 ± 1587.15 | 6976.19 ± 1260.41 |
| CRP (mg/L)         | 18.19 ± 5.13               | 31.92 ± 5.91 | 47.85 ± 11.28 |
| PCT (µg/L)         | 2.44 ± 0.65                | 2.39 ± 0.64 | 2.86 ± 0.76  |
The BMI, Ranson score, MCTSI score, and serum amylase level were all statistically significant ($p = 0.000, 0.000, 0.007, 0.002, 0.003, 0.023, 0.006, 0.001, 0.000, 0.000, and 0.017$). In the multivariate analysis, the BMI ($p = 0.035$), WBC ($p = 0.025$), serum calcium level ($p = 0.030$), and serum amylase level ($p = 0.020$) were all verified as independent risk factors for the severity of AP (Table 4).

### 3.3. The diagnostic value of BMI, WBC, serum calcium, and serum amylase in the severity of ABP

The ROC curve showed that BMI, WBC, serum calcium, and serum amylase had certain diagnostic values for the different severity of AP, but combined examination of the four factors had the highest diagnostic value, with the Area Under Curve (AUC) of 0.887 and the specificity of 77.5% and the sensitivity of 85.7% (Table 5, Figure 1).

### 4. Discussion

Acute pancreatitis is a common acute abdominal disease, as an inflammatory disorder of the pancreas. It takes a great economic cost for a lot of hospital admissions, especially for moderately severe and severe AP [44]. For this reason, the determination of the severity of AP in early stage is crucial for achieving good clinical outcomes and reducing costs. Until now, there are many different scoring systems for the severity of acute pancreatitis, including the Ranson score, MCTSI score, BISAP score, APACHE-II scores, et al [45, 46, 47, 48]. The severity of AP can be predicted based on clinical, laboratory, radiology, and biomarkers. However, the evaluation process of these scoring systems is too cumbersome, especially for the early judgment of SAP, and some scoring systems could only be estimated 48 h or more after admission. The good predictor should be rapid, inexpensive, and easy to be implemented. With the improvement of people’s living standards and changes in eating habits, the incidence of biliary tract diseases is getting higher and higher, and the resulting biliary pancreatitis is also gradually increasing. Therefore, we must evaluate the condition of AP as soon as possible.

The serological test is simple and fast, easy for dynamic observation, and has good clinical application value. At present, the most commonly used diagnostic indicator for AP is serum amylase, but serum amylase also tends to increase in patients with other abdominal diseases such as some biliary diseases, hepatitis, or tumors, while serum amylase in patients with pancreatic necrosis does not find an abnormal increase, and it is not directly proportional to the severity of the disease. Consequently, serum amylase is not the only index to judge the condition of AP [49]. The AP patients with severe stage often have elevated body temperature, elevated leukocytes, and organ dysfunction. Thus, the level of serum white blood cells (WBC) is an important reference factor to evaluate the condition of AP patients. In a prospective and multicenter study, the WBC and CRP level with in 24 h from the onset of pain were significantly lower in mild and moderately severe than in severe AP [50]. A similar result for WBC and CRP was found in our study, but not for PCT, although the severe patients had a higher level of PCT. The decrease in serum calcium level is correlated with the severity of AP, and it is one of the sensitive

**Table 4. The multivariate analysis of the risk factors for the severity of ABP.**

| Variables          | $p$       | OR     |
|--------------------|-----------|--------|
| BMI (kg/m²)        | 0.035     | 3.46   |
| WBC ($\times 10^9$/L) | 0.025     | 1.21   |
| Calcium (mmol/L)   | 0.30      | 0.05   |
| Serum Amylase (U/L)| 0.20      | 1.00   |

**Table 5. The diagnostic value of BMI, WBC, serum calcium and serum amylase in the severity of ABP.**

| Variables          | Cutoff value | Sensitivity | Specificity | AUC  |
|--------------------|--------------|-------------|-------------|------|
| BMI (kg/m²)        | 25.96        | 0.648       | 0.653       | 0.673 (0.576-0.771) |
| WBC ($\times 10^9$/L) | 11.77       | 0.648       | 0.694       | 0.726 (0.636-0.816) |
| Calcium (mmol/L)   | 2.14         | 0.648       | 0.653       | 0.320 (0.224-0.415) |
| Serum Amylase (U/L)| 1182.50      | 0.606       | 0.633       | 0.667 (0.571-0.762) |
| Combined Test      | 0.775        | 0.857       | 0.887       | 0.887 (0.810-0.934) |

**Figure 1. The ROC curve for BMI, WBC, serum calcium, serum amylase and combined test in the severity of ABP.**
factors to evaluate the severity of AP [51]. Low serum calcium level has been demonstrated that it played as an important role in judging patients with severe AP, which was verified as an independent risk factor [52, 53]. In our study, we also observed that the severity of APB was not only significantly related to the Ranson score and MCTSI score but also closely related to the patient’s WBC level, liver and kidney function, blood glucose, calcium, amylase, and other serological tests. These are similar to previous findings.

With the change in people’s lifestyle and dietary habits in recent years, the number of overweight and obese people is increasing. The BMI has become one of the most widely used evaluate the degree of obesity. Previous studies have shown that obesity is closely related to a variety of diseases, and more and more studies have shown that it may be related to the severity of acute pancreatitis, but fewer in China [54, 55, 56]. Lankishg PG et al. introduced BMI into acute pancreatitis for the first time in 1990, and proposed that obese patients were related to the acute occurrence of metabolic abnormalities, cholecystitis, hyperlipemia, and acute pancreatitis [57]. De Weale et al. have shown that being overweight and obese can obviously promote the occurrence of various complications of acute pancreatitis and are high-risk factors for severe patients [58]. To date, one prospective study (68,158 participants and 424 cases) has investigated the association of both BMI and Waist circumference (WC) with acute pancreatitis [59]. Most obese patients have a large amount of fat accumulation around the abdominal viscera. A lot of fat accumulated around the pancreas provides the basis for pancreatic bleeding, necrosis, and saponification. Fat decomposition releases a large amount of free fatty acids, which in turn damages pancreatic acinar cells and capillaries and accelerates the activation of trypsinogen. In addition, free fatty acids and chyle particles can block pancreatic capillaries, easily form microthrombosis, block pancreatic blood vessels, lead to pancreatic microcirculation disorder, release a variety of inflammatory factors, aggravate systemic inflammatory response syndrome, and easily complicated with multiple organ failure. The condition of acute pancreatitis in obese patients may be more serious and the incidence of complications is higher [60, 61, 62, 63]. Consistent with these previous studies, the BMI level of ABP patients is not only closely related to the Ranson score and MCTSI score of patients, but also the higher proportion of overweight and obese patients with the increase of score, and it is more prone to complications in our observations. The latest study showed that the obese patients carried an increased risk for longer hospitalization, morbidity, and mortality [64]. Although hyperglycemia is a more common cause of acute pancreatitis, and its prevalence is higher in obese and overweight individuals, the severity of disease and clinical outcomes are not significantly associated with it [65]. Our study supports this view, but it remains controversial [66, 67] and one of the reasons may be that the number of ABP patients in this study is too small. Moreover, BMI is also an independent risk factor for the severity of a patient’s condition, which also confirms the above view. Furthermore, according to these independent factors, we combined the BMI level, serum WBC, calcium, and amylase to predict the severity of APB with good sensitivity and specificity. This provides a good method for early judgment of the severity of APB in the future. However, there are several limitations to the study. This study is a retrospective single-center study, and it has a certain deviation in case screening. We expect to conduct a larger-sample, multicenter research to improve the reliability and value of the combined factors in future research.

5. Conclusion

In conclusion, patients with high BMI are more likely to develop more serious acute biliary pancreatitis. BMI is an independent risk factor for the severity of acute pancreatitis. Combined detection of BMI, serum WBC, calcium, and amylase levels will help to improve the early judgment of SAP, more conducive to early and timely detection and treatment, further reducing complications and mortality.

Declarations

Author contribution statement

Zhiixe Zheng: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.
Jing Tao Bi: Analyzed and interpreted the data.
Xuan Cai and Ya Qi Liu: Contributed regents, materials, and data.

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Data included in article/supp. material/referenced in article.

Declaration of interest’s statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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