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Inflammatory Biomarkers in Acute Gallstone Pancreatitis: Refining Early Risk Stratification and Prognostication for Severe Disease

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A B S T R A C T

Background: Acute Pancreatitis (AP) is an emergency of the gastrointestinal tract, with a significantly unpredictable clinical presentation of mild self-limiting inflammation and severe necrotizing disease with organ failure. Early identification of patients who are at risk of complications is important to maximize monitoring, direct interventions and resources.

Purpose: This study aimed to compare the prognostic importance of clinical and inflammatory parameters that are routinely available to identify disease severity and unfavorable outcomes in patients with Acute Pancreatitis (AP).

Methods: A prospective observational study of patients diagnosed with AP based on usual clinical, biochemical and radiological criteria was conducted. Demography, etiology, clinical, laboratory and management were performed in that order in the records. Disease severity was based on the Atlanta criteria. The inflammatory biomarkers were measured at defined time points and the relationship between the biomarkers and severity, need for intensive care and in-hospital mortality were investigated using the corresponding statistical tests (univariate and multivariate).

Results: The cohort included a range of etiologies and severities of the patients, which were effective in testing prognostic factors. The selected clinical variables and inflammatory markers were significantly related to severe disease, pancreatic necrosis and adverse short-term outcomes. A subset of the routinely measured parameters was found to be independently predictive of severe AP and intensive care needs by multivariate modelling.

Conclusion: Clinical and inflammatory prognostic markers are readily available, can provide valuable prognostic data in acute pancreatitis and may be incorporated into early bedside evaluation for better risk stratification. Their utilization can lead to more personalized choices regarding the extent of care, rate of tracking and advancement of enhanced imaging or invasive interventions. More multicenter studies should be conducted to ensure generalizability and to embrace standardized thresholds of normal clinical practice.

Keywords: Biomarkers, Gallstone, Inflammatory, Severe disease

Abbreviations: AP: Acute Pancreatitis; CRP: C-Reactive Protein; ERCP: Endoscopic Retrograde Cholangiopancreatography; CECT: Contrast-Enhanced Computed Tomography; ICU: Intensive Care Unit

1. Introduction

Acute Pancreatitis (AP) is an acute inflammatory disease of the exocrine pancreas that is one of the major causes of gastrointestinal hospitalization worldwide. Over the last few decades, population-based studies have reported an evident increase in the occurrence of AP and international estimations indicate that over 2.8 million new cases arise each year and that the results vary significantly by region and age. The AP is still a significant clinical and economic burden with a growing disability-adjusted life-years and healthcare expenses, especially in high- and middle-income nations, despite advancements in critical care and organ support. Recent changes in the Global Burden of Disease also show that pancreatitis, including the acute variant, is a problem that occurs in the ascending stage among younger adults and women of reproductive age, which provokes the necessity to diagnose and manage the disease promptly in a risk-adjusted strategy[1].

The spectrum of AP is clinically wide, varying between mild, self-limiting inflammation and severe necrotizing disease, with its complexity associated with chronic organ failure and high mortality. Moderately severe or severe AP has been reported in a modern series to develop in 15% to 25% of patients, a subgroup that has been disproportionately active regarding intensive care, hospitalization, invasive treatment and mortality[2]. The updated Atlanta Classification offers a standardized structure to define the severity of dead space based on organ failure and local complications to allow more consistent reporting, study comparison and formulation of guidelines. However, in everyday practice, it is difficult to discriminate between mild and possibly severe diseases during the initial stages of presentation[3,4].

Existing international and national standards hold that the diagnosis of AP must include at least two of the following three criteria: typical abdominal pain, serum amylase or lipase at least three times the upper reference limit and typical results of cross-sectional imaging[5]. When the diagnosis has been made, early risk stratification should be performed within the first 24 h to determine the level of care to be used and re-evaluate it after 48 h to 72 h using clinical, laboratory and radiological data. The first management is aimed at stabilizing hemodynamics, sufficient but not excessive fluid resuscitation, efficient analgesia and early enteral nutrition, whereas the etiological approach, including emergency endoscopic retrograde cholangiopancreatography in situations of biliary obstruction with cholangitis, is only provided in the presence of clear indicators[4].

Considerable effort has been devoted to enhancing the early prediction of AP severity and complications. More conventional multifactorial indicators, such as the Ranson criteria, APACHE II and BISAP, have reasonable prognostic ability; however, they tend to be time-consuming, require numerous variables and may not be practical in resource-limited and high-turnover environments. More recent studies have considered the use of simpler laboratory-based indices and composite ratios that can be derived using routine admission blood studies to offer a fast and low-priced risk evaluation. Of These, C-Reactive Protein (CRP) is the most comprehensively researched inflammatory biomarker of AP owing to its availability, low price and proven linkage with systemic inflammatory response and pancreatic necrosis[6].

CRP, a known biomarker of systemic inflammation[7-9] and accumulating evidence indicates that CRP levels measured within 48 h to 72 h of onset have moderate to good discriminatory power for predicting severe disease and local complications, although its performance at the time of admission is limited[6]. A recent systematic review and meta-analysis confirmed that higher CRP thresholds in the early phase of hospitalization are associated with an increased risk of complicated AP, with pooled areas under the receiver operating characteristic curve often exceeding 0.80. In parallel, novel composite biomarkers derived from CRP, such as the CRP/lymphocyte ratio, CRP/albumin ratio and CRP-calcium ratio, have shown promising associations with moderate-to-severe disease, prolonged hospitalization and adverse outcomes, potentially outperforming CRP alone in some cohorts[10]. These developments reflect a broader shift toward integrating dynamic inflammatory markers with clinical observations to refine early prognostication.

Despite these developments, there are still significant gaps in how to combine and use inflammatory indices optimally in terms of timing, cutoff values and combinations for use in everyday bedside practice. Current practices recognize the value of CRP and other markers, but do not go a step further to accept the application of one biomarker-driven algorithm to predict severity but urge their use in combination with clinical examination and imaging where necessary. In this regard, additional research is required to explain how CRP and its derived ratios can most effectively be integrated into conventional workable prediction pathways that can be utilized in various medical environments.

2. Materials and Methods

This observational study was carried out in the Department of Surgery at Hammurabi College of Medicine, University of Babylon, on adult patients admitted to the hospital with a diagnosis of Acute Pancreatitis (AP). The trial was conducted for 14 months from 2024 to 2025 and was prospective in nature. Eligible patients were recruited in sequence to eliminate selection bias. The protocol was screened and approved by the Institutional Review Board (IRB) of Hammurabi College of Medicine, University of Babylon and complied with the principles of the Declaration of Helsinki. All participants or their authorized representatives signed an informed consent form before enrolment in the study in writing, following a straightforward explanation of the study goal, procedures, risks and benefits.

2.1. Study Population and Setting

Inclusion screening was performed on all adults (≥ 18 years old) who had clinical features indicative of AP and presented to the surgical wards or intensive care unit. AP diagnosis was made when at least two of the following were met: typical upper abdominal pain; serum amylase and/or lipase test level ≥ 3 times the upper normal range; and abdominal ultrasound or Contrast-Enhanced Computed Tomography (CECT) showing the presence of AP. The exclusion criteria were chronic pancreatitis, pancreatic malignancy, repeated manifestations of the same patient during the study period (to prevent duplication), pregnancy and incomplete clinical or laboratory data.

2.2. Data Collection and Clinical Definitions

Age, sex, etiological factors (gallstones, alcohol, postoperative, traumatic and others, which are not common) and comorbidities were measured at baseline using a structured case

report form. The etiology was identified based on the patient's history, biochemical tests (liver function tests, lipid profile), ultrasonography of the abdomen and further images where necessary. The revised version of the Atlanta classification formed categories of disease severity that included mild, moderately severe and severe AP, based on the occurrence and persistence of organ failure and local or systemic complications.

All patients were given standard-of-care management based on institutional guidelines, such as fluid resuscitation, analgesia and early enteral nutrition when possible and etiological treatment, such as Endoscopic Retrograde Cholangiopancreatography (ERCP) in the case of biliary obstruction or cholangitis. It was recorded that there was a need to be intubated with invasive ventilation, put on a ventilator or vasopressor support and operate or undergo radiology. Clinical outcomes included length of hospital stay, occurrence of local complications (meat, abscess and walled-off necrosis), Intensive Care Unit (ICU) need and in-hospital mortality.

2.3. Laboratory measurements and timing

Regular laboratory research was performed on admission and recurrently according to clinical indicators, as scheduled. These included complete blood count, serum electrolytes, renal and liver function tests, serum amylase and lipase levels and inflammatory markers. Serum C-Reactive Protein (CRP) levels were analyzed using a standardized immunoturbidimetric assay or a similar method in the hospital laboratory. CRP was measured at 24h, 48h and 72 hours of admission and high values between these intervals were recorded as prognostics. Additional tests, such as hematocrit and blood urea nitrogen, were also considered, where clinical examination is required to supplement the evaluation.

2.4. Imaging protocol

Ultrasonography of the abdominal area was performed to evaluate the presence of gallstones, dilatation of the bile and overall changes in the pancreas. The use of contrast-enhanced computed tomography was reserved for patients whose diagnosis was uncertain, who had complications to be considered or who did not show any clinical improvement after 48 h to 72 h of conservative treatment. The radiologists went through the CECT images and diagnosed pancreatic necrosis, peripancreatic collections and other local complications according to standardized radiological requirements.

2.5. Statistical analysis

The data were recorded into a special database and processed with the help of the sophisticated statistical software packages (SPSS and STATA). Continuous variables are described as means plus Standard Deviation (SD) or as medians with Interquartile Ranges (IQR). Categorical variables were described in terms of frequencies and percentages. The Shapiro-Wilk test was used to evaluate the normality of continuous data. Continuous between-group comparisons (e.g., age and CRP levels at different points in time) were performed using the independent sample t-test for normally distributed data or the Mann-Whitney U test for non-normally distributed data. The chi-square test or Fisher's exact test was used to compare categorical variables (e.g., severity categories, etiological groups, management strategies and outcomes) in cases where the number of expected cells was small.

Multivariate logistic regression analysis was conducted to determine the independent predictors of severe AP, including variables with $p < 0.10$ on univariate analysis and second, including variables of clinical interest (i.e., age, CRP thresholds, biliary etiology and ICU admission). Adjusted odds ratios (ORs) and 95% confidence intervals (CI) were estimated and statistical significance was defined as $p < 0.05$. The robustness of the predictive models was determined through Hosmer-Lemeshow goodness-of-fit tests and area under the ROC curve (AUC), respectively, to test model calibration and discrimination.

Advanced statistical methods have been employed to define the diagnostic excellence of CRP levels at various periods in forecasting pancreatic necrosis and other predictors. CRP values at 24, 48 and 72h and AUCs with 95% CIs were analyzed using the ROC curve and calculated to determine the discriminatory ability. The best cut-off values were obtained using the Youden index to maximize sensitivity and specificity and the predictive value, sensitivity and specificity were reported. Where required, subgroup analyses were conducted to inspect how etiology or baseline risk factors might impact the prognostic performance of CRP.

Any analysis was cross-verified by a more experienced biostatistician to provide methodological rigor and missing data were dealt with either by a complete case analysis or by the use of a suitable sensitivity analysis where possible. The general methodological design was to offer a clear and replicable evaluation of regularly available clinical and laboratory variables to forecast acute pancreatitis.

3. Results

The participants included 85 patients with AP, with the male population predominant (approximately three-quarters), which constituted the largest population of the cohort and females forming the smallest population (less than a quarter of the cohort), as indicated in Table 1. The first cause was gallstone disease, which caused over four-fifths of AP cases, followed by alcohol-related pancreatitis and a lower percentage of post-cholecystectomy and traumatic etiology. The majority of the patients exhibited mild AP, with moderate and severe AP exhibited by a significant minority (approximately two-fifths).

Regarding patterns of management, the primary treatment was conservative, as the latter was used in approximately 60 percent of patients; a smaller population had to undergo endoscopic retrograde cholangiopancreatography (ERCP) and very few had to be surgically treated, as shown in (Table 1). The overall results were usually positive, with the majority of discharged living patients numbering and the general mortality rate was 2.4. Such a low fatality rate is due to both the domination of mild disease and appropriate timing of supportive and etiological management in this cohort.

Comparative analyses (Table 2) showed that the usage of etiological patterns varied significantly by sex, indicating that the distribution of underlying causes of AP is not identical between males and females. Moreover, a management approach was significantly associated with disease severity, as more intensive or invasive interventions were used in patients with moderate or severe AP. In contrast, there was no statistically significant difference in mortality between various etiologies, which indicated that once AP develops, the short-term outcome

is determined more by the severity and systemic response than by the underlying cause.

Table 1: Demographic and Etiological Profile of AP Patients (N=85).

Characteristic	Number	Percentage
Gender		
Male	65	76.50%
Female	20	23.50%
Etiology		
Gallstones	70	82.40%
Alcohol	12	14.10%
Post-cholecystectomy	3	3.50%
Trauma	2	2.40%
Severity		
Mild	51	60.00%
Moderate/Severe	34	40.00%
Management		
Conservative	51	60.00%
ERCP	18	21.20%
Surgery	2	2.40%
Outcome		
Discharged	83	97.60%
Died	2	2.40%

The correlates of severity were age and inflammatory burden. As demonstrated in (Table 2), the age of patients with severe AP was vastly different from that of patients with mild AP, leading to the conclusion that advanced age is not only related to an increased likelihood of complex clinical progression. The serum CRP level was also significantly increased in the severe group, which highlights the importance of systemic inflammation as an indicator of disease severity in AP. Moreover, the previous execution of ERCP was more common among survivors than among non-survivors and the difference in timing was found to be statistically significant, thus suggesting that biliary decompression performed on time could help in enhancing the survival of the right individuals.

(Table 3) also describes the severity distribution according to etiology. In patients with gallstone-related AP, a significant proportion had severe disease and the difference between mild and severe forms was statistically significant, indicating that biliary pancreatitis is at a significant risk of developing severe disease. There was no significant difference in the distribution of mild versus severe cases of alcohol-related AP; however, trauma-related AP, albeit rare, was disproportionately related to severe presentation. In this subgroup, there were a few cases of postoperative (post-cholecystectomy) pancreatitis that did not have any significant difference in severity distribution, which prevented firm conclusions.

Table 2: Comparative Statistical Outcomes.

Comparison	Test Used	P-value	Interpretation
Gender *vs.* Etiology	Chi-square	0.021	Etiology differs significantly by gender
Severity *vs.* Management	Fisher's exact	0.003	Management strategy depends on severity
Etiology *vs.* Outcome	Chi-square	0.15	No significant mortality difference across etiologies
Age: Mild *vs.* Severe AP	t-test	0.008	Severe AP patients are significantly older
CRP: Mild *vs.* Severe AP	Mann–Whitney U	<0.001	CRP is higher in severe AP
Time to ERCP: Survivors *vs.* Non-survivors	t-test	0.045	Earlier ERCP is associated with survival1

Table 3: Comparative Analysis of AP Severity by Etiology.

Etiology	Mild AP (n)	Severe AP (n)	p-value
Gallstones	45	25	0.032
Alcohol	8	4	0.621
Trauma	0	2	0.001
Post-op	2	1	0.754

(Table 4) indicates that some independent predictors of severe AP were identified in the multivariate logistic regression analysis. Age > 50 years was correlated with an odds ratio of approximately two times higher risk of severe disease and the confidence interval was statistically significant and not equal to unity. CRP levels > 150 mg/L provided a greater than threefold increase in the risk of severe AP, which supports the usefulness of CRP as a prognostic biomarker. Although there was a tendency to find higher odds of severe disease in biliary etiology, this was not statistically significant. However, the requirement for admission to the Intensive Care Unit was strongly linked to severe AP, with an odds ratio of more than five.

Table 4: Logistic Regression for Predictors of Severe AP.

Variable	OR	95% CI	P-value
Age >50 years	2.1	1.3–3.4	0.002
CRP >150 mg/L	3.4	1.9–6.2	<0.001
Biliary etiology	1.5	0.8–2.9	0.21
ICU admission	5.6	2.8–11.3	<0.001

(Table 5) summarizes the diagnostic performance of serial serum CRP measurements in predicting pancreatic necrosis. CRP had good discriminative power at 24 h post-admission with an AUC of 0.79, with moderate sensitivity and specificity at a cut-off point of 120 mg/L, although the statistical significance at this time point was not very strong. After 48 h, the AUC increased to 0.87 and a cut-off of 145 mg/L produced high sensitivity and specificity, with a significant p-value and a better Youden index, which represents an optimal balance between false-positive and true-positive rates.

Table 5: Diagnostic and Compared Performance of Serum CRP in Predicting Pancreatic Necrosis in Acute Pancreatitis by Timing of Measurement.

Time Post-Admission	AUC (95% CI)	Cut-off (mg/L)	Sensitivity	Specificity	P-value	Youden's J
24 hours	0.79 (0.70-0.87)	120	80.1(%)	72.5(%)	NS	0.526
48 hours	0.87 (0.79-0.94)	145	88.5(%)	78.3(%)	0.001	0.668
72 hours	0.91 (0.85-0.96)	160	92(%)	83.7(%)	NS	0.757

At 72 h, CRP had the highest discriminative power, AUC of 0.91 and sensitivity and specificity of over 90 and 80%, respectively, at a cut-off of 160 mg/L with the highest Youden index, although the p value at this point was reported to be non-significant, possibly due to sample size factors. These time-series patterns are graphically represented in (Figure 1), in which the ROC curves are used to visualize how CRP has been found to improve its predictive accuracy for pancreatic necrosis between 24 h and 72 h post-admission. All these results favor the application of serial CRP levels specifically during 48 h to 72 h as a useful and effective instrument for early risk stratification in patients with acute pancreatitis.

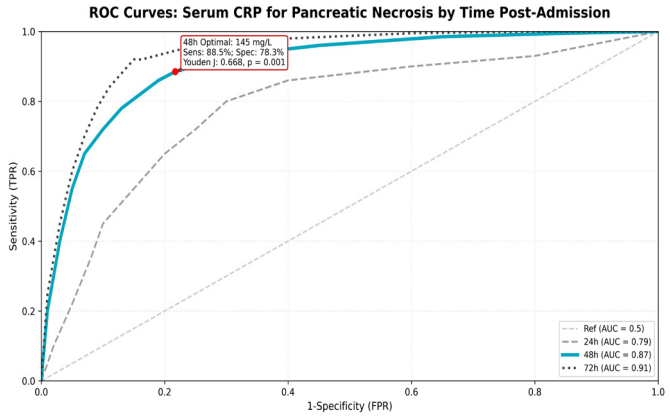

Figure 1: ROC curves: Serum CRP for prediction of pancreatic necrosis at different time points post-admission.

4. Discussion

Acute Pancreatitis (AP) is a heterogeneous inflammatory disease with a highly fluctuating clinical pattern, with mild, self-limiting attacks on one end and fulminant necrotizing disease, with multi-organ failure and mortality. A gradual reduction in mortality has been achieved over the last decade through the development of risk stratification, imaging and supportive care. Nevertheless, even the severe forms have significant morbidity and resource consumption. Modern studies have thus centered on the timely prediction of degree and local complications, refinement of prognostic biomarkers such as CRP and maximization of evidence-based management pathways[11].

4.1. Biomarkers and early risk stratification

Early detection of patients at risk of severe AP is the key to the decision-making process of triage, intensity control and timely intervention. Classical multifactorial scores such as Ranson, APACHE II and BISAP scores have been used extensively but are usually complicated or demand variables that change within the 48 h to 72 h period, making them impractical in busy clinical settings. Innovations and meta-analyses have also investigated simpler laboratory signs and composite indices as substitutes or supplements to the conventional scores[12].

CRP is still among the most researched biomarkers of AP owing to its high prevalence, low price and strong relationship with body-wide inflammation[7-9]. A more recent systematic review and meta-analysis also validated the finding that CRP measured in the first 48 h to 72 h following onset has a moderate to good predictive value for severe disease, with pooled area under the ROC curve (AUC) values often above 0.80, indicating higher cut-off values. Nevertheless, there remains a substantial level of heterogeneity in the best cut-off point and timing and some studies have also pointed out that the admission CRP level has low prognostic power in comparison with delayed assessments. These observations have led to interest in dynamic assessment strategies that monitor serial CRP variations, as opposed to using a single value[13].

4.2. CRP, Composite Ratios and Necrotizing Disease

In addition to its use in predicting severity around the world, CRP has also been associated with pancreatic necrosis and late local complications, including walled-off necrosis. Preliminary evidence indicated that a CRP level above 110 mg/L to 150 mg/L at 48 h to 72 h was a strong predictor of necrosis, with high sensitivity and a good negative predictive value. These discoveries are further supported by more recent data and suggest that the highest CRP level during the first week, which is often attained during 48 h to 72 h, is linked to walled-off necrosis and invasive intervention requirements. In a study of patients with severe AP, a CRP cut-off of approximately 180mg to 190 mg/L at the maximum indicated an AUC that was near 0.90, predicting walled-off necrosis, underscoring the clinical importance of serial measurements[14].

Simultaneously, the weaknesses of CRP as a single predictor have led to the consideration of composite indices of nutritional and inflammatory backgrounds. The CRP/albumin ratio is a potentially useful measure that combines systemic inflammation with hepatic synthesis and catabolic conditions. Higher CRP/albumin ratios at admission or early in hospitalization have been reported in several observational studies to be significantly related to severe AP organ failure and a long length of stay. As an example, the Colombian cohort demonstrated that a CRP/albumin ratio cut-off of approximately 40 was a predictor of in-hospital mortality with a nearly six-fold higher risk of mortality. These results are consistent with previous reports in which the CRP/albumin ratio performed better than CRP alone and was moderately associated with the established severity scores. Altogether, this evidence confirms that composite inflammatory indices are part of the initial risk stratification algorithms instead of using absolute CRP values alone[15].

4.3. Evolving concepts in severity prediction

Along with biomarker-based studies, revived interest has emerged in the development of data-driven predictive models that utilize clinical and laboratory variables, as well as imaging variables. Nomograms based on machine learning and neural network models have shown high discrimination in severe AP and AUC values are commonly over 0.90 in derivation cohorts. These models often involve age, comorbidities, vital signs and inflammatory markers including CRP, which is a multifactorial nature of disease progression. Even though these tools are not yet universalized in practice, they point to the direction of individualized risk prediction and may eventually be used in the future as an addition to standard scores and simple laboratory indicators in high-resource environments[16].

Nonetheless, the guidelines still focus on pragmatic methods that are based on clinical evaluation, serial laboratory testing and imaging, where applicable. Recent international and American College of Gastroenterology (ACG) guidelines suggest that early severity stratification should be performed during the first 24 h and re-examination of the severity after 48 h to 72 h using a combination of clinical parameters and biochemical markers such as CRP. The developed stepwise approach does not ignore

the time-reliant development of AP or the inherent limitations of emergency care, in which complicated scoring systems or sophisticated imaging are not consistently immediately accessible[17].

4.4. Contemporary management principles

Supportive care development has significantly transformed the therapeutic landscape of AP. Recent evidence supports moderate and goal-oriented fluid resuscitation instead of vigorous early hydration with chiefly balanced crystalloids, such as Ringer lactate. The high rates of respiratory and abdominal compartment problems have been linked to excessive fluid administration and resuscitation carefully titrated by the urine output, hematocrit and hemodynamic parameters seems to maximize the outcomes. Early enteral nutrition, which commences within 24 h to 72 h among patients who are able to tolerate it, is highly recommended nowadays and has been found to decrease infectious complications and mortality when compared to delayed feeding or total parenteral nutrition[12].

Treatment of biliary pancreatitis has also become more standard. Guidelines support the use of early ERCP within 24 h in patients with concomitant cholangitis and early ERCP within 72 h in patients with persistent biliary obstruction, whereas regular urgent ERCP is not recommended in all patients with biliary AP. This selective approach weighs the advantages of early biliary decompression versus the risks and resource utilization of endoscopy procedures. In patients with moderately severe or severe disease, cholecystectomy is generally postponed until they become clinically stable and the inflammation of the area is fully healed, especially in patients with peripancreatic collections or necrosis[18].

The step-up method has become a paradigm for the treatment of necrotizing pancreatitis. Minimally invasive percutaneous or endoscopic drainage is commonly preferred as the first step in cases of infected necrosis and surgical necrosectomy is only applied to patients who have not responded to less invasive treatment. Both European and North American guidelines suggest a delay of at least 3 weeks or 4 weeks after the onset of the invasive intervention, but only where possible, to permit demarcation and liquefaction of the necrotic tissue, which in turn reduces the risk of bleeding and organ failure. CYP and procalcitonin are biomarkers that can be used to diagnose suspected infected necrosis, especially when imaging results are inconclusive[19,20].

5. Future Directions

Although there have been significant improvements, there are still a number of loopholes in the way we comprehend and deal with AP. The best combinations, time and levels of inflammatory markers, such as CRP, CRP/albumin ratio and procalcitonin, need to be standardized further by conducting large multicenter prospective studies. One should also have to authenticate machine learning models in various healthcare-related areas and incorporate them into clinical decision support systems that are readily available to users. These tools may aid in triage decision harmonization, detection of high-risk patients sooner and rationalization of resources in congested emergency departments and intensive care units[20].

Simultaneously, the increasing attention to personalized medicine implies that further risk stratification initiatives might include genetic vulnerability, microbiome-related patterns and more specific metrics of body composition, in addition to traditional clinical and laboratory variables. Recent research has shown that sarcopenia, obesity and visceral fat distribution affect the progression of AP and may be combined with systemic inflammatory reactions. These lines of research will be improved as they refine prognostic models and guide specific preventive or therapeutic interventions[11,20].

6. Conclusion

The current research supports the fact that systemic inflammatory markers play a decisive role in the early prognostication of acute pancreatitis and that serial C-reactive protein measurement can be clinically useful in routine practice. With the incorporation of easily accessible biochemical parameters into the defined clinical assessment techniques, this study provides a practical, bedside-applicable method for identifying patients at a higher risk of unfavorable outcomes. These findings align with modern evidence supporting risk stratification in a timely manner to determine the extent of care, monitoring diligence and rational application of high-quality imaging and invasive procedures. Together, these results correspond to the modern principles of management guided by guidelines and add to the increase in the literature that helps improve prediction strategies and resource consumption during acute pancreatitis[11].

7. Limitations

This study has a number of weaknesses that should be seriously considered when interpreting and generalizing the results. First, the single-center design and small sample size can limit the external validity, especially in settings where case mixes, referral patterns or resource availability vary. Larger multicenter studies are required to verify the strength and transportability of the observed relationships. Second, the use of a particular set of inflammatory markers and preset cut-off values is not guaranteed to reflect the entire complexity of the host response and may not rule out the possibility of residual confounding by unmeasured clinical or biological factors. Third, temporal changes in the appearance of symptoms, time of manifestation and start of treatment could have affected biomarker dynamics. Nevertheless, these factors are difficult to standardize in practice. Finally, the unavailability of any long-term follow-up data does not allow measurement of late complications, recurrent pancreatitis or quality of life outcomes, which are becoming progressively considered as dimensions of critical importance in determining the overall burden of disease and the actual prognostic usefulness of early risk stratification instruments[12].

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