Pancreatic Phospholipase A₂ Activity in Acute Pancreatitis: a Prognostic Marker for Early Identification of Patients at Risk

Johannes Aufenanger¹, Michael Samman², Michael Quintel³, Klaus Fassbender⁴, Wilma Zimmer⁵ and Thomas Bertsch⁵*

¹Institute for Laboratory Medicine, Clinic Ingolstadt, Teaching Hospital of the Ludwig Maximilians University Munich, Ingolstadt, Germany
²Center for Laboratory Medicine, Microbiology and Transfusion Medicine, Clinic Karlsruhe, Teaching Hospital of the Albert Ludwigs University Freiburg, Karlsruhe, Germany
³Institute for Anaesthesiology and Surgical Intensive Care,
⁴Department of Neurology,
⁵Institute for Clinical Chemistry, Clinic Mannheim of the Ruprecht Karls University of Heidelberg, Mannheim, Germany

Remarkably elevated levels of phospholipase A₂ (PLA₂) are measurable in human blood samples in cases of acute pancreatitis. The source of the enzyme was first thought to be exclusively the pancreas, but now it is generally accepted that two isoenzymes – the pancreatic PLA₂, group I, and the extrapancreatic PLA₂, group II – contribute to the raised activity. In contrast to the group II-PLA₂, the pancreatic PLA₂ is heat-resistant for 1 hour at 60 °C. The catalytically inactive proenzyme of the pancreatic PLA₂ can be activated by trypsin. The aim of our study was to evaluate the diagnostic value of PLA₂ isoenzyme activity measurements to identify patients with severe complications in acute pancreatitis. Blood samples from patients suffering from acute pancreatitis were analyzed for catalytically active pancreatic PLA₂ (Pa PLA₂) out of the total serum PLA₂. The Pa PLA₂ is secreted as a zymogen which means that a cleavage from an inactive form is necessary to achieve enzymatic activity. This zymogen for Pa PLA₂ is called prophospholipase A₂ (Pro PLA₂). It is not inducible by cytokines.

A group II-PLA₂ which is released from blood cells and probably from the liver, especially during inflammation (4). This enzyme is inducible by proinflammatory cytokines (5). It is not secreted as a zymogen. Therefore in studies on the measurements of PLA₂ activity in acute pancreatitis a differentiation between the different PLA₂ forms is necessary (6).

Until now it has not been possible to determine specifically the activity of the pancreatic PLA₂ (group I). Since it plays a very important role in the pathogenesis of acute pancreatitis, its measurement would provide helpful information on diagnosis and, above all, prognosis of the disease. We have developed a sensitive assay to measure the fraction of catalytically active pancreatic PLA₂ (Pa PLA₂) out of the total serum PLA₂. The present study is, to our knowledge, the first one comparing total PLA₂, Pa PLA₂ and Pro PLA₂ activity with the acute phase reactants CRP and polymorphonuclear elastase (PMN-elastase).

Abbreviations: CRP, C-reactive protein; MAB, monoclonal antibody; Pa PLA₂, catalytically active pancreatic phospholipase A₂; PLA₂, phospholipase A₂; PMN, polymorphonuclear; Pro PLA₂, prophospholipase A₂.

Introduction

The value of serum-phospholipase A₂ (PLA₂) activity in acute pancreatitis as prognostic and diagnostic marker is controversial. Until the late 80’s PLA₂ levels in acute pancreatitis were believed to be exclusively of pancreatic origin. The group I-PLA₂ concentration determined with an immunoassay correlated closely with lipase and amylase (1). Soon it became evident that the course of total serum PLA₂ activity did not correlate with the kinetics of other pancreatic enzymes but followed those of inflammatory indicators like C-reactive protein (CRP). It was of interest that the serum PLA₂ remained high after total pancreatic necrosis, and even after total pancreatectomy (2). From these observations it was concluded that two immunologically different isoenzymes are responsible for elevated serum PLA₂ levels in cases of acute pancreatitis.

The heat-resistant pancreatic PLA₂ (Pa PLA₂) group I which probably occurs only in pancreatic diseases (3). Pa PLA₂ is secreted as a zymogen which means that a cleavage from an inactive form is necessary to achieve enzymatic activity. This zymogen for Pa PLA₂ is called prophospholipase A₂ (Pro PLA₂). It is not inducible by cytokines.

Key words: Acute pancreatitis; Phospholipase A₂; Isoenzymes; C-reactive protein; Elastase.
Patients and Methods

This study included 41 patients with acute pancreatitis who were admitted to the Mannheim Department of Surgery at the University of Heidelberg. Twenty six patients were male and 15 were female. The mean age was 57 years. Twenty one patients suffered from biliary pancreatitis and 14 from alcoholic acute pancreatitis. In three cases pancreatic inflammation followed endoscopic retrograde cholangiopancreatography (ERCP) and in one case it was caused by excessive hyperlipidemia (triglycerides >11.4 mmol/l). In two patients the cause of pancreatitis remained obscure. On average, patients with mild disease had 0.3 complications (Table 1), patients with severe pancreatitis had 3.4 complications and patients who died had on average 3.5 complications. All patients with mild disease had edematous pancreatitis, whereas severe and lethal outcomes were predominantly necrotizing pancreatitis. Almost all patients of this group had to undergo laparotomy. This procedure which involves early removal of necrotic pancreatic tissue with subsequent drainage of the peripancreatic space was preferred in our department.

The diagnosis of acute pancreatitis was confirmed by typical symptoms, elevated amylase level (normal values <32 U/l) and characteristic changes in ultrasonography and computerized tomography. Once the diagnosis was established, the following laboratory parameters were determined daily: amylase, PMN-elastase, CRP and serum PLA2. The day of hospitalization was defined as day 1. The severity of the disease was assessed by the clinical outcome and the number of complications that occurred (7). Patients were classified into two groups: mild pancreatitis, i.e. less than or equal to one complication (n=31) and severe/lethal pancreatitis, i.e. greater than or equal to two complications or lethal outcome (n=10, Table 1).

α-Amylase was determined photometrically (Beckman, Munich, Germany), CRP and PMN-elastase were determined immunologically (Merck, Darmstadt, Germany).

Total serum PLA2 as well as Pa PLA2 and Pro PLA2 were measured by modifications of the radioactive E.coli-based assay described recently in detail (5, 8, 9). Instead of TRIS/HCl as reaction buffer, an acetate buffer (100 mmol/l; pH 6.0) was used described recently in detail (5, 8, 9). Instead of TRIS/HCl as re-

Results

The inhibition of the Pa PLA2 and Pro PLA2 activity by a monoclonal antibody specific for human pancreatic PLA2 is shown in Figure 1. The antibody was able to completely inhibit the activity observed before or produced by trypsin activation (p<0.002). This confirms that the pancreas is the source of Pa PLA2 and Pro PLA2.

In the patient group with mild disease both Pa PLA2 and Pro PLA2 were mostly elevated on the first day of hospitalization but remained rather low (less than 6.8 U/l). Both correlated temporally but not with respect to the amount of increase (Figure 2). The measurement of amylase does not allow conclusions about the expected increase in Pa PLA2 or Pro PLA2 activity. In contrast to amylase, particularly the Pa PLA2 activity depends on the severity of the disease. After the second day Pa PLA2 activity was low or not detectable. In the sera from patients with severe disease much higher values of Pa PLA2 were observed (7.2 to 81.2 U/l). Here too, the maximum was usually reached on the first day of hospitalization. In this group of patients Pro PLA2

Table 1 Complications of acute pancreatitis in the studied patients.

<table>
<thead>
<tr>
<th>Complication</th>
<th>Mild (n=31)</th>
<th>Severe (n=8)</th>
<th>Lethal (n=2)</th>
<th>All (n=41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia, atelectasis, pleural effusion</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Respiratory insufficiency (paO2&lt;60 mmHg)</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Ascents, retroperitoneal effusion</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Ileus</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Consumptive coagulopathy</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cholangitis/cholecystitis</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Renal failure</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Encephalopathy</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pancreatic pseudocyst</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Cholestasis</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Upper gastrointestinal bleeding</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Sepsis</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Shock</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>
levels were somewhat higher. Further, serum PLA2 activity reached its maximum on day 3 and did not show any correlation with other pancreatic enzymes.

We investigated five laboratory parameters to define their potential use for an individual prognosis. They were determined in samples from each patient on day 1 and 2 of hospitalization, but only the higher of the two values was used for statistical calculations. Except for Pa PLA2, all other parameters were not reliable concerning prognosis in individual cases, although they proved to be of statistical value (Table 2). Figures 3 and 4 show an interesting comparison between total serum PLA2 and Pa PLA2 with regard to initial assessment of prognosis. According to the nonparametric U-test, serum PLA2 was well able to differentiate between mild and severe/lethal pancreatitis (p=0.0061), but Figure 3 shows clearly that this has no meaning for the individual patient. For PMN-elastase the situation appears to be similar (Table 2). Its values differed significantly between the two groups (p=0.033) but did not allow reliable conclusions concerning clinical outcomes. According to this study, the CRP maxima on the first 2 days of hospitalization could not even differentiate between mild and severe pancreatitis, in contrast to PMN-elastase (p=0.476). Pro PLA2 values can differentiate only with marginal significance (p=0.051), and sensitivity and specificity (0.60 and 0.65, respectively) suggest that this test is not suitable for clinical use. In contrast, the situation for Pa PLA2 activity is completely different. In both groups the values did not even overlap, so that mild (edematous) and severe (necrotizing) forms of the disease could be readily distinguished (Table 2, Figure 4). The calculation of the cut-off values for the best diagnostic sensitivity and specificity for the total serum PLA2 activity and the pancreatic PLA2 activity was per-

![Figure 1](image1.png)  
**Figure 1** Inhibition of pancreatic phospholipase A2 by a monoclonal antibody (MAB) (n=10). a: Activities measured after heating for 60 minutes (Pa PLA2) and b: after additional incubation with trypsin for 5 minutes (Pro PLA2). c: and d: Activities after addition of an inhibitory MAB specific for human pancreatic PLA2. Complete inactivation was observed in all samples.

![Figure 2](image2.png)  
**Figure 2** Time course of enzyme activities (medians) after admission to the hospital. Pa PLA2 and Pro PLA2 show obvious similarity to amylase. In contrast, serum PLA2 does not correlate with pancreatic enzymes.

| Table 2 | The measurement of phospholipases and inflammation statistical data. |
|---------|-----------------|-----------------|-----------------|-----------------|-----------------|
|         | Serum- PLA2     | Pa PLA2         | Pro PLA2        | CRP             | Elastase        |
| Cut-off | 100 U/l         | 7 U/l           | 15 U/l          | 300 mg/l        | 200 µg/l        |
| Sensitivity | 60%             | 100%            | 60%             | 40%             | 60%             |
| Specificity | 83.9%           | 100%            | 65%             | 87.1%           | 74.2%           |
| PPV^1    | 54.5%           | 100%            | 37.5%           | 50%             | 42.9%           |
| NPV^2    | 86.7%           | 100%            | 84%             | 81.8%           | 85.2%           |
| p-Value^3 | 0.0061          | <0.0001         | 0.051           | 0.476           | 0.033           |

^1positive predictive value; ^2negative predictive value; ^3differentiation between mild and severe disease
serum PLA2 does not allow a reliable individual prognosis. Specificity (see also Table 2) indicate that the measurement of severe/lethal pancreatitis. However, the low sensitivity and (p<0.0001) seem to show a clear difference between mild and between the medians and the high level of significance (n=10); of hospitalization.

alytically active pancreatic PLA2 seems to be a good in-

Figure 3 Maximal activity of total serum PLA2 on days 1 or 2 of hospitalization. ● patients with severe/lethal pancreatitis (n=10); ○ patients with mild pancreatitis (n=31). The comparison between the medians and the high level of significance (p<0.0001) seem to show a clear difference between mild and severe/lethal pancreatitis. However, the low sensitivity and specificity (see also Table 2) indicate that the measurement of serum PLA2 does not allow a reliable individual prognosis.

formed by receiver operating characteristics (ROC) analysis and discrimination analysis.

Discussion

One of the most important questions concerning acute pancreatitis is the early differentiation between mild and severe forms of the disease. Laboratory tests such as lipase and amylase and also computerized tomography and ultrasonography serve as sufficient means to diagnose this dangerous disorder. However, the assessment of the individual prognosis by these means still remains questionable (11).

Although these results must be interpreted with caution due to the rather small number of patients, the catalytically active pancreatic PLA2 seems to be a good indicator of the pancreatic damage. Acute pancreatitis is an autodigestive disease in which digestive enzymes synthesized in the pancreatic acinar cells destroy the gland. Schmidt and Creutzfeldt came to the conclusion that pancreatic PLA2 might be responsible for the glandular and periglandular tissue necrosis (12, 13). These findings have been confirmed by others (14, 15). It can be assumed that elevated activities of Pa PLA2 in serum reflect necrotizing processes in the pancreas itself as well as extrapancreatic organ failures such as pulmonary or renal complications initiated by this enzyme. This is supported by the finding that Pa PLA2 activity is detectable in peritoneal effusion and pleural fluid during acute pancreatitis (16, 17). From there, the Pa PLA2-enriched fluids diffuse to pulmonary structures with subsequent destruction of the lungs. Furthermore, intraperitoneal Pa PLA2 leads to enhanced translocation of bacteria through the intestinal wall into the mesenteric lymph nodes with subsequent bacteremia (18). Additionally, Pa PLA2 causes a marked decrease in the pancreatic blood flow and damage to intra-abdominal nerve plexus followed by the inhibition of intestinal motility (19).

Interestingly, total PLA2 serum activity kept increasing until day 3 despite decreasing Pa PLA2 and Pro PLA2 activities. This is due to increasing PLA2-II activity. It is suggested that this enzyme may also be responsible for multiorgan failure in acute pancreatitis because this is the key enzyme for the eicosanoid mediator synthesis. Therefore PLA2-II inhibitors were developed and tested (20, 21). This early increase in Pa PLA2 followed by an increase in PLA2-II could also be demonstrated in cerulein-induced acute pancreatitis in rats (22). Furthermore, our CRP measurements are consistent with the previous studies of other authors (23) and of our group which demonstrated that CRP is not a useful tool to distinguish between mild and severe forms of acute pancreatitis (24).

In conclusion, we demonstrated that Pa PLA2 activity in serum is strongly elevated in severe acute pancreatitis and that it allows a discrimination between mild and severe forms of this disease in its early phase. As this enzyme may at least in part contribute to multiorgan failure, we suggest that it is worthwhile to develop and test specific inhibitors of Pa PLA2 or proteinase inhibitors which would inhibit the cleavage of the active enzyme from Pro PLA2.

References


Received 15 August 2001, revised 18 January 2002, accepted 21 January 2002

Corresponding author: Dr. Thomas Bertsch, Institut für Klinische Chemie, Klinikum Mannheim der Universität Heidelberg, Theodor-Kutzer-Ufer 1–3, 68167 Mannheim, Germany
Phone: +49 621 383 3483, Fax: +49 621 383 3819
E-mail: thomas.bertsch@ikc.ma.uni-heidelberg.de