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# Bacteriological and biochemical features of peritonitis in perforative pyloroduodenal ulcer

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*Despite a wide range of available surgical interventions, the optimal strategy for perforated pyloroduodenal ulcers, including cases combined with other complications, remains undetermined. The use of conventional techniques in patients with peritonitis is often associated with purulent-septic complications. The aim of the work was to investigate the pathophysiological features of peritonitis in perforated pyloroduodenal ulcer and their influence on the course of this disease. The study included 158 patients aged 20-73 years, divided into three groups according to the duration of peritonitis: up to 6 h (n = 99), 6-12 h (n = 35), and more than 12 h (n = 24). All patients underwent bacteriological examination, measurement of abdominal exudate pH at different stages of peritonitis, and analysis of clinical and laboratory parameters. The duration of peritonitis was found to be associated with a higher degree of bacterial contamination of the abdominal cavity. Within 60 minutes after perforation, the initially acidic gastric contents in the abdominal cavity become neutralized; at an exudate pH of 7, optimal conditions for pathogenic microflora are established. Thus, the presented clinical, laboratory and bacteriological results indicate that during the first 3-5 days of the early postoperative period, the patient's body continues to fight the consequences of post-perforation peritonitis.*

*Key words: pyloroduodenal ulcer; perforation; peritonitis; pH-metry; bacteriological contamination.*

## INTRODUCTION

The problem of treating gastric and duodenal ulcers remains relevant in modern abdominal surgery. Despite the development and successful use of contemporary conservative treatment methods, there has been no decrease in the frequency of complications such as bleeding and perforation in this pathology [1]. In the pathogenesis of pyloroduodenal ulcers (PDU), the principal factor is the acid-peptic effect, while an additional factor that significantly aggravates the disease course is *Helicobacter pylori* infection [2]. It is generally accepted that during the first 12 hours after PDU perforation, the abdominal exudate is characterized by low bacterial contamination, which supports consideration of radical procedures (pyloro- or duodenoplasty with of anti-relapse treatment or limited gastric resection) rather than palliative interventions (suture of the perforation) [3, 4]. This type of surgical approaches not only eliminate complications but may also achieve complete recovery [5, 6]. Surgical intervention for perforated PDU, depending on the severity and extent of peritonitis, addresses several key objectives: elimination of the source of peritonitis (treatment of the ulcer), removal of exudate from the abdominal cavity, and management of the consequences of peritonitis (drainage and lavage of the abdominal cavity with antiseptic solutions, along with comprehensive conservative therapy) [7, 8]. Failure to adhere strictly to these principles may allow a range of pathological factors to promote progression of the acute inflammatory process in the abdominal cavity after surgery, leading to multiple organ failure and death [9]. The most dangerous factors associated with an unfavorable course of peritonitis include chemical injury to the peritoneum caused by the entry of aggressive gastric or duodenal contents containing hydrochloric acid and

proteolytic enzymes through the perforation, as well as bacterial contamination with insufficient sanitation and inadequate drainage of the abdominal cavity [10].

The aim of the work was to investigate the pathophysiological features of peritonitis in perforated PDU and their influence on the course of this disease.

## METHODS

The work was conducted during 2019-2025 at Department of Surgery with a course in abdominal surgery of Bogomolets National Medical University and was approved by the Commission on Bioethical Expertise and Ethics of Scientific Research (Protocol No. 125, dated October 21, 2019). The study included the results of treatment of 158 patients with diffuse or disseminated peritonitis caused by perforated PDU. Exclusion criteria were critical condition of the patient, decompensated concomitant pathology, combination of ulcer perforation with bleeding, and refusal to participate in the study.

The average age of the patients was 34.2 ± 11.6 years (range 20-73 years), there were 122 men (77.2%) and 36 women (22.8%). Comorbidities were present in 65 patients (41.1%), with the most common being chronic diseases of the cardiovascular (49 patients, 31%) and bronchopulmonary systems (15 patients, 9.5%). The patients were hospitalized within 1 to 72 h from the moment of perforation, with the mean time of 13.3 ± 11.7 h.

In 136 patients (86.1%), the ulcer was located in the duodenum, and in 22 patients (13.9%) in the pyloric part of the stomach. Among those with duodenal ulcers, 124 patients (91.2%) had the ulcer in the duodenal bulb, while 12 patients (8.8%) had an extra-bulbar location. The perforation and ulcerative infiltrate were most commonly isolated and located on the anterior wall of the duodenum (104 patients, 76.5%) or the pyloric part of the stomach (17 patients, 77.3%). Analysis of ulcer size showed that 142 patients (89.9%) had ulcers ranging from 0.6 to 1.9 cm, with a mean size of 1.2 ± 0.4 cm. During surgery, 57 patients (36.1%) were found to have ulcer perforation combined with other complications of peptic ulcer disease: stenosis in 43 patients (27.2%) and penetration into neighboring organs in 14 patients (8.9%).

All patients underwent surgery. To investigate the pathophysiological features of the inflammatory process in the abdominal cavity, bacteriological studies were performed. Cultures were obtained on solid media using generally accepted methods, followed by incubation in a thermostat for 7 days. In cases of growth, microorganisms were identified using cultural, bacterioscopic, and biochemical methods according to the Bergey's Manual of Bacterial Identification; pH of abdominal exudate was measured at different stages of peritonitis using a portable pH meter/thermometer pHep®, HI 98128, Germany. Based on the results of bacteriological examination of abdominal exudate in relation to the time since perforation, patients were divided into three groups: the first - 99 patients (62.7%) with a duration of peritonitis up to 6 h; the second - 35 patients (22.2%) with 6-12 h; and the third - 24 patients (15.2%) with more than 12 h. The groups did not differ significantly in age (32.8 ± 12.1, 35.3 ± 12.1, and 34.9 ± 11.1 years, respectively; $P > 0.05$), sex distribution (men 76.8%, 77.1%, and 79.2%; women 23.2%, 22.9%, and 20.8%, respectively; $P > 0.05$), or the presence of comorbidities (41.4%, 40.0%, and 41.7%, respectively; $P > 0.05$).

To identify optimal conditions for the development of microflora characteristic of peritonitis in perforated PDU, exudate cultures were performed on media (Endo, Sabouraud, yolk-salt agar, and 5% blood agar) at different pH levels (2, 5, 7, and 9) in 101 patients (63.9%). After surgery, all patients were treated in the intensive care unit, which allowed body temperature to be monitored every two hours. The main clinical signs of peritonitis regression were normalization of the motor-evacuation function of the intestine, including the appearance of regular peristaltic sounds on auscultation, passage

of gas, independent stool, and resolution of abdominal distension. The leukocyte count in peripheral and the leukocyte intoxication index were determined daily.

Statistical analysis was performed using MedCalc® (version 23.1.7, 64-bit; available as an open-access online resource at https://www.medcalc.org). Normality of data distribution was assessed using the Shapiro–Wilk test. Differences between groups were evaluated using Student's t-test for independent samples, and differences in distributions were assessed using the $\chi^2$ test. Results are presented as mean ± standard deviation (M ± SD), as well as relative values (proportions) and interval estimates. Differences were considered statistically significant at $P < 0.05$.

## RESULTS

The results of bacteriological examination of abdominal exudate in patients with perforated PDU are presented in Table.

In patients of group 1, the microflora was represented by Gram-positive cocci (*Staphylococcus epidermidis, Staphylococcus saprophyticus, Streptococcus viridans, Streptococcus pneumoniae*), Gram-negative bacilli (*Klebsiella pneumoniae, Proteus mirabilis, Morganella morganii, Escherichia coli*), and fungi of the genus *Candida*. Monoculture was observed in 21.9% (7/32) of patients, while bacterial associations were detected in 78.1% (25/32). In group 2, microflora growth was observed in 26 patients (74.3%), and its composition did not differ significantly; monoculture was present in 7 patients (26.9%), and bacterial associations in 19 patients (73.1%). In all patients of group 3, bacterial associations were observed, with additional detection of enterobacteria and opportunistic microorganisms (*Proteus vulgaris, Proteus corrodens, Pseudomonas aeruginosa, Escherichia coli, Enterobacter aerogenes, Enterobacter cloacae, Enterococcus faecalis*), as well as fungi of the genus *Candida albicans*. The observed changes in the nature of the microflora in this group may be explained by bacterial translocation associated with the development of intestinal paresis.

Analysis of the frequency of detection of microorganisms in abdominal exudate, depending on the nature and extent of peritonitis, is presented in Fig. 1.

It was found that the lowest frequency of microflora detection was observed in serous localized (7.5% of cases) and diffuse peritonitis (15.4% of cases). At the same time, the presence of microflora in the exudate in 100% of patients with diffuse serous peritonitis (with a duration from the moment of perforation not exceeding 6 h) can be explained by the fact that in all cases there was a large perforation defect or an almost complete rupture of the duodenum at the site of perforation. These were patients with giant ulcers, which were often accompanied by duodeno- and gastrostasis.

The study of abdominal exudate pH revealed values of 7.0-7.7, regardless of the duration of perforation, size of the perforation, or the nature and extent of peritonitis. This can be explained

**Results of bacteriological examination of abdominal exudate in patients with different durations of peritonitis**

| Result | Patient groups (duration of peritonitis, n) | | |
|---|---|---|---|
| | Group 1 (≤ 6 h, n = 99) | Group 2 (6-12 h, n = 35) | Group 3 (≥ 12 h, n = 24) |
| Presence of microflora growth | 32 (32.3%) | 26 (74.3%) *** | 24 (100%)***/## |
| Absence of microflora growth | 67 (67.7%) | 9 (25.7%) * | None (0%) |

Notes: ***P < 0.001 compared with group 1; ##P < 0.01 compared with groups 2; **P < 0.01 compared with group 1.

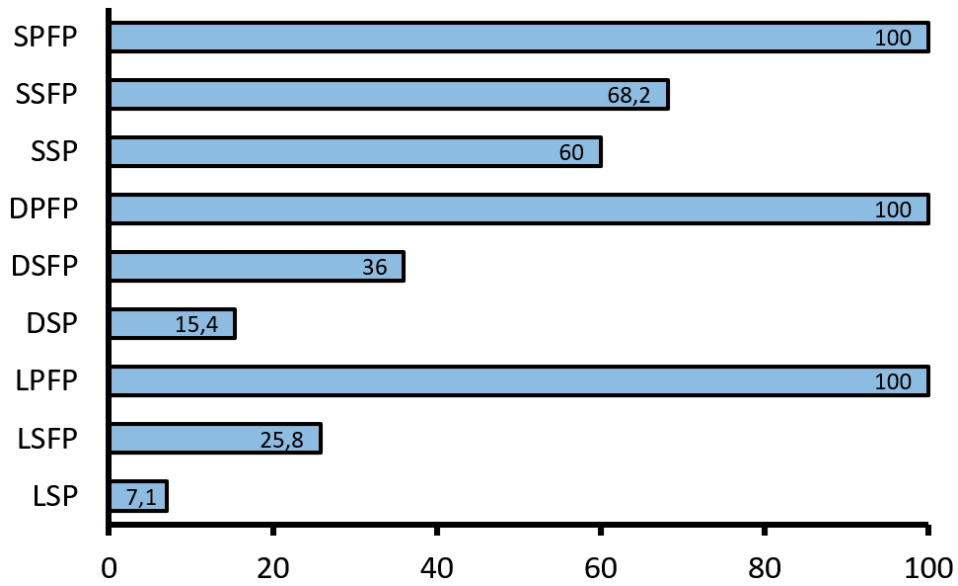


Fig. 1. Frequency of microorganism detection in abdominal exudate depending on the nature and extent of peritonitis. LSP - local serous peritonitis; LSFP - local serous-fibrinous peritonitis; LPFP - local purulent-fibrinous peritonitis; DSP - diffuse serous peritonitis; DSFP - diffuse serous-fibrinous peritonitis; DPFP - diffuse purulent-fibrinous peritonitis; SSP - spilled serous peritonitis; SSFP - spilled serous-fibrinous peritonitis; SPFP - spilled purulent-fibrinous peritonitis

by the rapid (within 60 ± 6.7 min) neutralization of acidic gastric contents entering the abdominal cavity through the perforation by bicarbonates and ammonia compounds accumulating in the peritoneal fluid.

The data obtained during bacteriological examination of abdominal exudate using media with different pH levels are presented in Fig. 2.

Analysis of these results showed that the highest number of positive cultures (100%) was obtained at a medium pH of 7.0, indicating that this pH provides optimal conditions for the growth of microflora from exudate in perforated PDU.

When comparing the timing of body temperature normalization, leukocyte count in

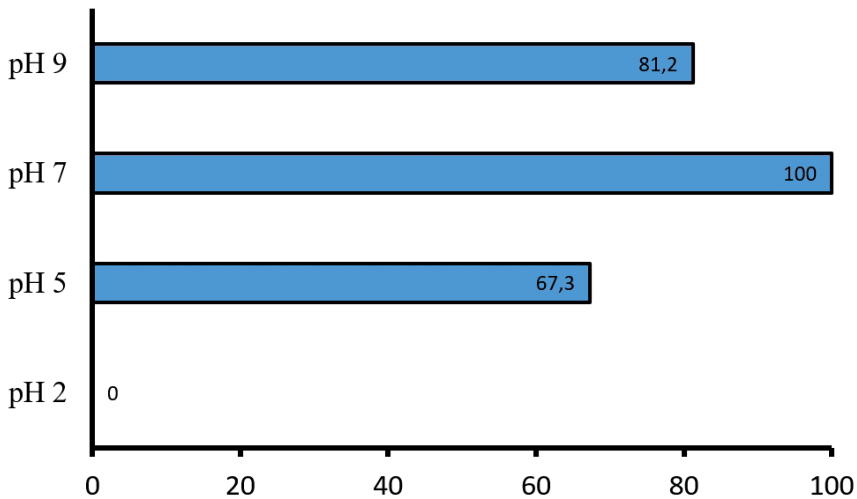


Fig. 2. Frequency of positive bacteriological results of abdominal exudate at different pH levels

blood serum, leukocyte intoxication index, and restoration of intestinal peristalsis in patients with similar exudate characteristics and peritonitis extent, no significant differences were observed ($P > 0.05$).

It should be noted that data from purulent forms of peritonitis were not included, as positive bacteriological results were obtained in all patients. Therefore, for patients with the same degree of abdominal cavity damage (based on the nature of the exudate and the extent of peritonitis), there was no significant difference in the mean time to normalization of the selected indicators of peritonitis resolution, since differences between corresponding pairs of mean values were not statistically significant ($P > 0.05$).

## DISCUSSION

Despite the development of conservative treatment methods for gastric and duodenal ulcers, the incidence of complications associated with this disease has not shown a significant decrease [11]. Moreover, although a wide range of surgical interventions is available, the optimal surgical management of perforated PDU, including cases combined with other complications, remains undetermined [12]. The use of generally accepted surgical techniques (particularly suturing of perforated ulcers) in purulent peritonitis, especially in the presence of edematous tissue, can often lead to the development of purulent-septic complications [6].

In this study, we found that with increasing duration of peritonitis in perforated PDU, the proportion of positive bacteriological results of abdominal exudate significantly increased from 32.3% to 100% ($P < 0.05$), while opportunistic microflora appeared and bacterial associations predominated. The lowest frequency of microflora detection was observed in local and diffuse serous peritonitis. However, in diffuse serous peritonitis, positive bacteriological results in all patients of group 1 can be explained by the large size of the perforation (>1 cm), which likely facilitated more rapid entry of the bacterial factor together with alkaline duodenal contents into the abdominal cavity.

Analysis of the results of bacteriological examination of abdominal exudate at different pH levels showed that the highest number of positive culture results was obtained at a medium pH of 7.0. Therefore, it can be concluded that this pH provides optimal conditions for the growth of microflora in perforated PDU.

A comparative analysis of the timing of the decrease in systemic inflammatory response indicators in patients, depending on the nature and extent of peritonitis, revealed that in patients with perforated PDU, the inflammatory process in the abdominal cavity persists during the first 3-5 days of the postoperative period, necessitating comprehensive conservative treatment. At the same time, no clinically significant differences were observed in the severity of patients' condition or in the course of peritonitis between cases with positive bacteriological results of abdominal exudate and those without microflora growth (aseptic peritonitis). Therefore, this form of peritonitis shares common clinical features with bacterial peritonitis.

These findings suggest that the absence of microflora growth in exudate obtained during the first hours after perforation cannot be considered an absolute indication of sterility of the abdominal cavity, as previously believed [5]. This is further supported by individual cases of covered PDU perforations, in which only a limited amount of gastric juice enters the abdominal cavity, with further leakage prevented by closure of the perforation by various factors. Nevertheless, due to the rapid neutralization of hydrochloric acid, optimal conditions for bacterial growth are quickly restored in the abdominal cavity [6].

The question of the need for cost-effective gastric resection arises mainly in cases of perforation of so-called "complex" duodenal ulcers, which include giant ulcers (over 3 cm)

complicated by circular tubular stenosis [13]. In our study, all patients in this category had positive bacteriological results of abdominal exudate. We believe this can be explained by the large size of the perforation, which allows a substantial amount of alkaline duodenal contents to enter the abdominal cavity, a process further facilitated by concomitant pyloro- and/or duodenostasis.

Thus, within an hour after perforation, the acidic gastric contents entering the abdominal cavity through the perforation are neutralized, and optimal conditions for the growth of pathogenic microflora are restored.

Therefore, the commonly used criteria for selecting the surgical approach, based on the duration of peritonitis from the moment of perforation, cannot serve as an objective indicator of the nature of peritoneal inflammation (abacterial phase versus bacterial contamination) and should not be used alone to justify surgical strategy. The presented clinical, laboratory, and bacteriological findings indicate that during the first 3-5 days of the early postoperative period, the patient's body continues to respond to the consequences of post-perforation peritonitis.

## CONCLUSIONS

1. The duration of peritonitis in perforated pyloroduodenal ulcer correlates with the degree of bacterial contamination of the abdominal cavity.

2. On average, within 60 ± 6.7 min after perforation, neutralization of acidic gastric contents that have entered the abdominal cavity occurs.

3. At an exudate pH of 7.0, optimal conditions for bacterial contamination are created.

4. The well-known criteria for choosing the method of surgical intervention, based on the time frame of the duration of peritonitis from the moment of perforation, cannot serve as an objective indicator of the nature of peritoneal inflammation (abacterial phase, bacterial contamination) and be used to justify surgical tactics.

5. The presented clinical, laboratory and bacteriological results indicate that during the first 3-5 days of the early postoperative period, the patient's body continues to fight the consequences of post-perforation peritonitis.

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**БАКТЕРІОЛОГІЧНІ ТА БІОХІМІЧНІ ОСОБЛИВОСТІ ПЕРИТОНІТУ ПРИ ПЕРФОРАТИВНИХ ПІЛОРОДУОДЕНАЛЬНИХ ВИРАЗКАХ**

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Незважаючи на широкий спектр оперативних втручань, і дотепер остаточно не визначена тактика хірургічного лікування перфоративних пілородуоденальних виразок, у тому числі в поєднанні з іншими ускладненнями. Використання загальноприйнятих хірургічних методик в умовах перитоніту може нерідко призводити до розвитку гнійно-септичних ускладнень. Метою нашої роботи було дослідити патофізіологічні особливості перебігу перитоніту при перфоративній пілородуоденальній виразці та їх вплив на перебіг захворювання. Дослідження базувалось на результатах обстеження 158 осіб у віці 20–73 років, які були розділені на три групи: перша – 99 пацієнтів з тривалістю перитоніту впродовж 6 год, друга – 35 хворих – 6–12 год та третя – 24 пацієнти – понад 12 год. Усім хворим проводили бактеріологічне дослідження та визначення pH ексудату з черевної порожнини у різні терміни розвитку перитоніту, аналіз клініко-лабораторних показників. Було виявлено, що тривалість перитоніту при перфоративній пілородуоденальній виразці прямо пропорційна ступеню бактеріальної контамінації черевної порожнини. Протягом 60 хв після перфорації

відбувається нейтралізація кислого шлункового вмісту, що потрапив у черевну порожнину та при значенні pH ексудату 7 створюються оптимальні умови для розвитку патогенної мікрофлори. Таким чином, представлені клінічні, лабораторні та бактеріологічні результати свідчать про те, що протягом перших 3–5 днів раннього післяопераційного періоду організм пацієнта продовжує боротьбу з наслідками постперфораційного перитоніту.

Ключові слова: пілородуоденальна виразка; перфорація; перитоніт; pH-метрія; бактеріологічне забруднення.

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