Comparative Evaluation of Various Methods of Drainage of the Abdominal Cavity in Patients with Secondary Bacterial Peritonitis

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Abstract
Background: Secondary peritonitis is a serious complication of all the inflammatory diseases and injuries of the abdominal organs and requires urgent surgical intervention. The mortality rate of patients with secondary bacterial peritonitis (SBP) reaches 70%. In some patients, despite the treatment, secondary peritonitis turns into tertiary peritonitis (TP), which complicates the healing process and aggravates the prognosis. Inadequate drainage of the abdominal cavity is a possible contributing factor to the formation of TP.

Objectives: A prospective study of the result of surgical treatment of patients with SBP was carried out to improve the results of treatment.

Methods: The study included 608 patients with SBP who underwent surgery in a clinical hospital in Russia in 2013-2019. All the patients were divided into groups depending on the method of draining the abdominal cavity and on signs of the purulent process generalization, the marker of which was multiple organ failure. Efficiency of abdominal drainage (by the incidence of TP) and of treatment results (in terms of mortality) were assessed in each group.

Results: In patients without signs of the purulent process generalization, drainage of the abdominal cavity with drainage tubes (293 observations) is accompanied by the development of TP in 4.1% of cases and by mortality in 22.9%. If the purulent process is of a generalized nature (315 observations), the incidence of TP increases ten-fold and is 41.9%, and the mortality rate increases 2.7 times and reaches 62.8%. With the generalization of the purulent process, the efficiency of drainage of the abdominal cavity has a significant impact on the results of surgical treatment of patients with SBP. If abdominal drainage is carried out with drainage tubes (129 observations), the incidence of TP is 41.9%, and the mortality rate is 62.8%. Drainage of the abdominal cavity using traditional laparostomy (Bogota bag, 104 cases) is accompanied by the development of TP in 36.5% of cases and mortality in 45.2%. If the abdomen is drained using active laparostomy (VAC-system, 82 observations), the incidence of TP is reduced to 18.3% and mortality to 19.5%.

Conclusion: Drainage of the abdominal cavity is the most important stage of surgical intervention in patients with SBP. In cases of the purulent process generalization, drainage of the abdominal cavity in the most effective way—by active laparostomy (VAC-system) will improve the results of treatment of these patients.

Keywords: Abdominal Cavity Drainage, Secondary Bacterial Peritonitis, Tertiary Peritonitis, VAC-system.

Introduction
Peritonitis is a serious surgical problem that often complicates the clinical course of inflammatory diseases and injuries of the abdominal organs. In most cases, surgeons deal with secondary peritonitis, that is, with peritonitis resulting from a violation of the integrity of the abdominal organs. These disorders can be both obvious and subtle, developing due to a decrease in the barrier function of the intestinal tube caused by an acute inflammatory process in the abdominal cavity. The inflammatory process in the abdomen entails the formation of serous fluid which, on average, turns into pus with progressive inflammation after 12 hours. Bacterial seeding of the abdominal cavity activates local defense mechanisms, which are accompanied by the release of biologically active substances and their absorption through the extensive capillary network of the peritoneum. The entry of biologically active substances into the bloodstream leads to a systemic inflammatory reaction of the body and then to multiple organ failure. The larger the area involved in the pathological process of the peritoneum, the stronger the systemic inflammatory response and the deeper the multiple organ failure. If the inflammatory process occupies more than two areas of the abdominal cavity, peritonitis is considered common. Multiple organ failure in a patient with peritonitis indicates that the absence of the sepsis phase and then the sepsis phase turned either into the severe sepsis phase or into the septic shock phase. The mortality rate when the clinical course of peritonitis is accompanied by multiple organ failure reaches 70%.
Such high mortality rate is recorded in groups of elderly and senile patients, when peritonitis lasts several days and is widespread. The key stage in the treatment of patients with peritonitis is the earliest possible surgical intervention which should eliminate the source of peritonitis and thoroughly sanitize the abdominal cavity. If the source of peritonitis is eliminated, the abdominal cavity is sanitized, and the peritonitis does not show a tendency to regression 48 hours after the operation, the development of tertiary peritonitis (TP) is stated.\textsuperscript{2,8,16,25}

One of the factors possibly contributing to the development of TP is inadequate drainage of the abdominal cavity. Fluid accumulations in the abdomen, formed as a result of unsatisfactory drainage, are a favorable environment for microorganisms.

According to various authors, TP is diagnosed in 3-20% of patients operated on for secondary peritonitis.\textsuperscript{2,4,8,10,11,13,20,23,24,25} TP develops in patients weakened by prolonged and severe illness, with poor nutritional status and a depleted immune system.\textsuperscript{2,3,10,13} It is caused by a low-virulent (under normal conditions) nosocomial flora: gram-negative and gram-positive microorganisms such as enterobacteria (Klebsiella spp., Enterobacter spp., Ps. Aeruginosa, Acinetobacter baumannii), enterococci (Enterococcus faecium), coagulase-negative staphylococci (CoNS), methicillin-resistant Staphylococcus aureus (MRSA) as well as fungi of the genus Candida.\textsuperscript{11,16,17,20,25,26} The conducted antibiotic therapy, aimed at the causative agents of secondary peritonitis, ‘clears’ the place for the nosocomial flora, and the weakened organism is unable to resist it.

The literary sources analyzed by the authors of the present study offered no clear data on the influence of the efficiency of abdominal drainage on the results of surgical treatment of patients with SBP.

**Objectives**

The study was aimed to find ways to improve the results of surgical treatment of SBP.

To achieve this goal, the following tasks were set:
1. to justify the need to for the present study;
2. to evaluate the effectiveness of various methods of drainage of the abdominal cavity in patients with SBP;
3. to compare the effectiveness of various methods of drainage of the abdominal cavity in patients with SBP;
4. to assess the impact of the efficiency of abdominal drainage on the results of treatment of patients with SBP.

**Materials and Methods**

A prospective study of the treatment of patients with SBP who underwent surgery in 2013-2019 in a clinical hospital in Russia was carried out. During the above period, 19871 patients were operated on urgently in the hospital. Patients in whom SBP was confirmed intraoperatively were candidates for inclusion in the study.

**Inclusion criteria:** Age over 18, the secondary nature of peritonitis, the purulent nature of the effusion, the involvement of more than two areas of the abdominal cavity in the purulent-inflammatory process.

**Exclusion criteria:** Pregnancy, early postpartum period, postoperative peritonitis.

The inclusion criteria were met by 608 patients in whom peritonitis was a complication of an acute surgical disease or abdominal trauma and served as an indication for emergency surgery.

To substantiate the need for the present study, the incidence of SBP among patients undergoing emergency surgery and the results of its surgical treatment were studied. The incidence was defined as the ratio of the number of patients with SBP to all the patients undergoing emergency surgery.

The result of surgical treatment of SBP was assessed in terms of postoperative mortality.

To assess the methods of drainage of the abdominal cavity, all the patients were divided into groups depending on the method of drainage used.

The closed drainage group (CD) included 422 patients; the abdominal drainage was carried out by the closed method– drainage tubes were installed in the areas of possible fluid accumulation and the surgical wound was sutured tightly.

The traditional laparostomy group (TLS) (the Bogota bag analogue) included 104 patients. The abdominal drainage was carried out by the open method– after the elimination of the source of peritonitis and sanitation of the abdomen, perforated plastic wrap was placed on the bowel loops, and afterwards two large surgical gauze napkins which absorb the fluid forming in the abdomen and, through an open surgical wound, transfer the absorbed fluid into a bandage which also consists of large surgical napkins.
The active laparostomy group (ALS) (the VAC system analogue) included 82 patients in whom the abdomen was drained with a device for active aspiration of fluid from the abdominal cavity (RF patent No. 126587, 174545, 174544). After elimination of the source of peritonitis and sanitation of the abdominal cavity, the above-mentioned device was installed in the abdomen and connected to a constant vacuum source using a drainage tube. The abdominal cavity was sealed with an adhesive surgical tape, and the fluid formed in the abdomen was continuously evacuated for 24 hours.

The effectiveness of each method of abdominal drainage was assessed by the incidence of TP. TP was considered when it had no tendency to resolve in 48 hours after adequate surgical treatment of SBP.

Surgical intervention was considered adequate when it completely eliminated the source of contamination, and sanitation and drainage of the abdominal cavity were performed according to generally accepted surgical canons - washing the abdomen with at least five liters of saline and draining the abdominal cavity by the closed or open method.

The rate of TP development was calculated as the ratio of the number of patients with TP to patients operated on for SBP.

Comparing the frequency of TP development in each group allowed comparing the effectiveness of drainage methods – the lower the frequency of TP development, the more effective the drainage method. Notably, the groups must be comparable for the comparison of the effectiveness of different abdominal drainage methods to be correct.

Therefore, the CD group was divided, depending on the number of operations performed, into the single operation group (SO) and the repeated operations group (RO).

The RO group was comparable to the TLS group and the ALS group and could correctly participate in the comparison of the drainage efficiency of different methods.

To assess the impact of the efficiency of abdominal drainage in patients with SBP, the mortality rate in each group was compared with the incidence of TP.

**Statistical analysis**

Statistical processing of the data was carried out using the statistical package of the Microsoft Excel program, using the t-test and methods of simple statistics for comparing different groups. The differences between the compared parameters were recognized as significant at p < 0.05.

**Ethical consideration**

The study was conducted in accordance with the Declaration of Helsinki. Institutional Review Board approval was obtained. The present study did not interfere with the process of diagnosis and treatment of patients. All data were extracted from the patients’ medical records.

**Results**

For seven years, 19871 patients underwent urgent surgery. Of these, 608 patients (3.1% of the total number of urgently operated patients) had SBP, and 211 of these died (34.7% mortality) (Table-1). The average age of 608 patients with peritonitis (314 male, 294 female) was 61.7±17 years. The severity of peritonitis according to the MPI was 27.2±7.3 points, and the initial severity of patients according to the SOFA was 2.8±2.3 points.

These patients were divided into CD, TLS or ALS groups depending on the method of drainage used (Table-2). The closed drainage group (CD) included 422 patients (208 male, 214 female, average age 61.1±17 years). MPI was 26.8±5.2 points, SOFA was 2.5±2.0 points. Of the 422 patients in the CD group, TP occurred in 66 patients (15.6%), and 148 patients died (35% mortality).

The traditional laparostomy group (TLS) (the Bogota bag analogue) included 104 patients (56 male, 48 female, average age 64.8±19 years). TP occurred in 38 patients (36.5%), and 47 patients died (45.2% mortality). MPI was 32.1±7.3 points, SOFA was 4.5±2.3 points.

The active laparostomy group (ALS) (the VAC system analogue) included 82 patients (45 male, 37 female, average age 62.1±16 years). TP was recorded in 15 patients (18.3%), and 16 patients died (19.5%). MPI was 33.1±7.5 points, SOFA was 4.1±2.2 points.

For the comparison of the effectiveness of different abdominal drainage methods the CD group was divided into SO and RO (Table-3). The SO group consisted of 293 patients, 100 male, 183 female, average age 65.3±18 years. TP occurred in 12 patients (4.1%), and 67 patients died (22.9% mortality). MPI was 23.4±5.2 points, SOFA 2.1±1.8 points.

The RO group consisted of 129 patients, 98 male, 31 female, average age 59.8±22 years. TP occurred in 54 patients (41.9%), and 81 patient died (62.8% mortality). MPI was 30±8.0 points, SOFA 4.1±1.8 points.
Table 1. Results of surgical treatment of patients with SBP

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Observations</th>
<th>CD group</th>
<th>TLS group</th>
<th>ALS group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations (%)</td>
<td>608 (100)</td>
<td>499 (69.4)</td>
<td>104 (17.1)</td>
<td>82 (13.5)</td>
</tr>
<tr>
<td>TP patients (%)</td>
<td>119 (19.6)</td>
<td>66 (15.6)</td>
<td>38 (36.5)</td>
<td>15 (18.3)</td>
</tr>
<tr>
<td>Deceased (%)</td>
<td>211 (34.7)</td>
<td>148 (35)</td>
<td>47 (45.2)</td>
<td>16 (19.5)</td>
</tr>
</tbody>
</table>

Secondary bacterial peritonitis SBP, closed drainage group CD, tertiary peritonitis; TP, active laparostomy group ALS, traditional laparostomy group TLS

Table 2. Characteristics of groups of patients with SBP and generalization of the purulent process.

<table>
<thead>
<tr>
<th>Investigated indicator</th>
<th>RO group</th>
<th>TLS group</th>
<th>ALS group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number (%)</td>
<td>129 (30.5)</td>
<td>104 (55.9)</td>
<td>82 (44.1)</td>
</tr>
<tr>
<td>Male/Female</td>
<td>98/31</td>
<td>56/48</td>
<td>45/37</td>
</tr>
<tr>
<td>Average age (yrs)</td>
<td>59.8±22</td>
<td>64.8±19</td>
<td>62.1±16</td>
</tr>
<tr>
<td>MPI (points)</td>
<td>30±8.0</td>
<td>32.1±7.3</td>
<td>33.1±7.5</td>
</tr>
<tr>
<td>SOFA (points)</td>
<td>4.1±1.8</td>
<td>4.5±2.3</td>
<td>4.1±2.2</td>
</tr>
<tr>
<td>TP (%)</td>
<td>54 (41.9)</td>
<td>38 (36.5)</td>
<td>15 (18.3)*</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>81 (62.8)</td>
<td>47 (45.2)</td>
<td>16 (19.5)*</td>
</tr>
</tbody>
</table>

* p < 0.05, repeated operations group; RO, secondary bacterial peritonitis; SBP, tertiary peritonitis; TP, active laparostomy group; ALS, traditional laparostomy group; TLS

Table 3. CD group divided depending on the number of operations performed

<table>
<thead>
<tr>
<th>Investigated indicator</th>
<th>SO Group</th>
<th>RO group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number (%)</td>
<td>293 (69.4)</td>
<td>129 (30.6)</td>
</tr>
<tr>
<td>Male/Female</td>
<td>110/183</td>
<td>98/31</td>
</tr>
<tr>
<td>Average age (yrs)</td>
<td>65.3±18</td>
<td>59.8±22</td>
</tr>
<tr>
<td>MPI (points)</td>
<td>23.4±5.2</td>
<td>30±8.0*</td>
</tr>
<tr>
<td>SOFA (points)</td>
<td>2.1±1.8</td>
<td>4.1±1.8*</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>67 (22.9)</td>
<td>81 (62.8)*</td>
</tr>
</tbody>
</table>

* p < 0.05, closed drainage group; CD, single operation group; SO, repeated operations group; RO

Discussion

SBP is a regular complication of acute inflammatory diseases and injuries of the abdominal organs. As mentioned above, 608 patients with this condition were treated over a seven-year period, making 3.1% of all the urgently operated patients (1987)1, which allows predicting the annual admission of up to 100 (86.8) such patients to the 1,500 hospital.

Analysis of the studied patients indicates they are mostly elderly (average age 61.7±17 years), and their significant part has second- or third-degree peritonitis (MPI 27.2±7.3 points) accompanied by multiple organ failure (SOFA 2.8±2.3 points). The expected range of mortality in this case is 20-60%,2,7,8,11,16,19,20,26,27 and the addition of multiple organ failure indicates that the purulent process in the abdomen has a generalized character and is either in the severe sepsis phase or in the septic shock phase.

Evaluation of the treatment results of these patients revealed a postoperative mortality rate of 34.7%, which confirms the relevance of this study and is consistent with the data of other works on the topic, which estimate the mortality rate after surgical treatment of peritonitis between 15% and 70%.2,7,8,11,16,19,20,26,27

The assumption that inadequate drainage of the abdominal cavity can contribute to the formation of TP and affect the results of treatment of patients with SBP required dividing all patients into groups according to the method of abdominal drainage used, investigating the incidence of TP in each group and conducting a comparative study of the effectiveness of each method of abdominal drainage.

For the comparison results to be correct, a preliminary comparative analysis of the main parameters characterizing the groups was carried out. A comparative analysis of these parameters determined that the TLS group and the ALS group are comparable in terms of the main indicators but significantly differ from the CD group in terms of the severity of peritonitis (MPIts 32.1±7.3 points, MPIals 33, ±7.5 points, MPIcd 26.8±5.2 points, p=0.043, p=0.045, respectively) and the severity of the initial state of patients (SOFAts 4.5±2.3 points, SOFAals 4.1±2.2 points, SOFAcd
2.5±2.0 points, p=0.045, p=0.048, respectively).

Differences between groups by the severity of peritonitis and the severity of the initial state of patients indicated that in many cases among the TLS group and the ALS group, peritonitis was in the severe sepsis phase or in the septic shock phase, and the purulent process had signs of generalization. These signs were absent in a significant part of patients of the CD group, since peritonitis was in earlier phases of development - the absence of sepsis phase or the sepsis phase. Therefore, at this stage of the study, a correct comparison of treatment results and drainage efficiency is possible only between groups in which open abdominal drainage techniques were used (TLS group and ALS group), and the CD group requires additional study.

In the process of in-depth analysis of the clinical material, attention was drawn to the fact that in almost all the patients of the TLS group and the ALS group, surgical treatment of the SBP was carried out in several pre-programmed stages.

In the CD group, 129 patients (30.6%) re-underwent operations in the on demand mode which implies repeated unplanned emergency surgery due to the lack of effect from the primary surgery or due to the development of a life-threatening complication. The need for repeated unplanned emergency surgery in the CD group suggests that in some of these patients, the initial intervention was ineffective and led to the development of TP. To test this hypothesis, the CD group was divided into the single operation group (SO) and the repeated operation group (RO).

A comparative analysis of the newly formed groups showed that they significantly differ in the severity of peritonitis (MPls 23.4±5.2 points; MPlr 30.1±5.0 points, p=0.039) and in the severity of the initial state (SOFAs 2.1±1.8 points; SOFAr 4.1±1.2 points, p=0.047). These differences suggest that the purulent process in patients of the SO group was much less pronounced and is in earlier stages of development than in patients of the RO group that, according to the abovementioned characteristics, resembles the TLS group and ALS group more in showing signs of generalization of the purulent process; however, the drainage of the abdominal cavity was carried out by the closed method – using drainage tubes.

Mortality rates in the CD groups also significantly differ from each other (p <0.05) – 22.9% (67/293) in the SO group, that is, 2.7 times lower than in the SO group with 62.8% (81/129). The difference in mortality rates in groups with different severity of purulent processes is not surprising, since a more severe purulent process implies a higher mortality.

Notably, in patients who did not have signs of generalization of the purulent process (the SO group), the completion of the surgical treatment of SBP by draining the abdominal cavity using drainage tubes is accompanied by the development of TP in 4.1% of cases (12/293). In cases where purulent inflammation in the abdomen was of a generalized nature (the RO group), the completion of the operation by closed drainage of the abdominal cavity is accompanied by the development of TP in 41.9% of patients (54/129), that is, 10 times more often (p<0.05).

Perhaps, with the generalization of purulent inflammation, the physicochemical characteristics of the inflammatory fluid change – it turns into viscous pus, which makes it difficult for the drainage tubes to work effectively.

The tenfold difference in the incidence of TP allows concluding that in 30.6% of patients in the CD group (the RO group) drainage of the abdominal cavity was ineffective and, possibly, influenced the outcome of surgical treatment.

The found comparability of the RO group, the TLS group and the ALS group in terms of the severity of peritonitis and the severity of the initial state allows their correct comparative analysis.

An analytical comparison of the main characteristics of these groups demonstrated their comparability in terms of size, sex, age, severity of peritonitis and severity of the initial state. Certain differences were recorded in terms of the incidence of TP and mortality.

In the RO group, the incidence of TP reaches 41.9% (54/129), in the TLS group, it is 36.5% (38/104), and in the ALS group, it is 18.3% (15/82). The different incidence of TP in groups that are comparable in terms of the main indicators but differ in the method of drainage of the abdominal cavity allows asserting that in patients with SBP, the methods of drainage of the abdominal cavity used are unequally effective.

Comparative analysis of the incidence of TP revealed that in the ALS group, TP was 2.3 times less frequent than in the RO group (p<0.05) and 2 times less frequent than in the TLS group (p<0.05).

Significant differences in the incidence of TP allow concluding that abdominal drainage using ALS is more effective than TLS in patients with SBP with signs of generalization of the purulent process.
Results of treatment of patients with a generalized purulent process in the abdomen showed that mortality in the RO group reaches 62.8% (81/129), in the TLS group, it is 45.2% (41/104), and in the ALS group, it is 19.5% (16/82).

Comparative analysis of mortality rates showed maximum value in the RO group—1.4 times higher than in the TLS group (p<0.05) and 3.2 times higher than in the ALS group (p<0.05). Comparing the incidence of TP and mortality rates showed that in the studied groups, an increase in the incidence of TP is accompanied by an increase in the mortality rate.

The revealed regularity allows concluding that the efficiency of drainage of the abdominal cavity has a significant impact on the results of surgical treatment of patients with SBP with signs of generalization of the purulent process.

Conclusions
The study confirmed that SBP is an urgent problem of abdominal surgery, being present in 3.1% of emergency surgeries and accompanied by the mortality rate of 34.7%.

In 19.7% of patients operated on for SBP, TP is formed in the postoperative period, significantly complicating the healing process. The mortality rate of patients with TP reaches 84%, which represents 47.4% of all the patients who died after surgical treatment of SBP.

The phase of purulent inflammation, in which surgical treatment of SBP is started, plays the key role in the formation of TP. If the surgical treatment begins with symptoms of generalization of the purulent process, TP develops much more often than when the operation is performed before the septic process damages the main body systems.

In case of generalization of the purulent process, the efficiency of abdominal drainage is of particular importance and has a significant impact on the results of treatment of patients with SBP. The ALS method has the maximum drainage efficiency, yet is complicated by the development of TP in 18.3% of cases and accompanied by a mortality rate of 19.5%. The capabilities of drainage pipes and TLS are much more modest. Drainage of the abdominal cavity by means of TLS leads to the development of TP in 36.3% of patients and mortality in 45.2%. If silicone tubes are used to drain the abdomen, TP develops in 41.9% of cases, and the mortality rate reaches 62.8%.

The study clearly demonstrated that in patients with SBP, complete surgical elimination of the source of peritonitis and thorough sanitation of the abdominal cavity should be accompanied by reliable and effective drainage. This is especially true for patients with generalization of the purulent process—ineffective drainage creates conditions for the transformation of secondary peritonitis into tertiary peritonitis, which significantly reduces the chances of recovery.

The authors of the present research believe that, in the absence of contraindications, signs of generalization of the purulent process should serve as the reason to complete the surgical intervention by an active laparostomy (VAC system)—the most effective way of draining the abdominal cavity. This maneuver will reduce the likelihood of developing TP and significantly improve the results of treatment of patients with SBP.

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Authors’ Contribution
All authors pass the four criteria for authorship contribution based on the International Committee of Medical Journal Editors (ICMJE) recommendations.

Conflict of Interests
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