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Comparative Evaluation of Intra-Operative Peritoneal Lavage with Super-Oxidized Solution and Normal Saline in Peritonitis Cases

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ABSTRACT

Background: Acute generalized peritonitis is a serious surgical emergency and often secondary to perforation of the gastrointestinal tract and carries a high risk of postoperative morbidity and mortality. Intraoperative peritoneal lavage is routinely done to minimise bacterial contamination. Traditionally, normal saline is the solution used, but super-oxidized solution (SOS), due to its broad-spectrum antimicrobial properties, could be beneficial as well in preventing postoperative infections. The present study was designed to compare the effectiveness of SOS and normal saline in intra-operative peritoneal lavage in peritonitis patients.

Methodology: This was a prospective, randomized comparative study carried out in the General Surgery Department, Geetanjali Medical College & Hospital, Udaipur from 2023 to 2026. There were a total of 220 patients split into two groups of 110 patients each. Both groups received initial peritoneal lavage with 1L of normal saline after definitive surgical management. Group I was then given 200mL of diluted SOS while Group II was given another 200mL of normal saline. Solutions were retained IP for 1 hour, with drains clamped. Outcomes were postoperative bacterial growth, wound infection, severity of wound infection, wound pain, wound discharge, time at hospital, time to drain removal, return of bowel sounds, and overall postoperative complications. Appropriate tests were used for statistical analysis, and a significance level of $p < 0.05$ was used.

Results: Group I showed significantly better bacterial clearance at 72 hours postoperatively when compared to the other groups ($p = 0.01$, $p = 0.03$, and $p = 0.02$ for patients having gastric, ileal, and jejunal perforations, respectively). There were significantly fewer postoperative wound infections in Group I than in Group II (27.3% vs. 40.9%, $p = 0.003$). The occurrence of wound pain was also significantly reduced in Group I (27.3% vs. 63.6%, $p<0.01$), and purulent wound discharge (25 vs 63, $p<0.01$). The mean duration of hospital stay was shorter in Group I (8.98 ± 1.30 vs. 9.60 ± 1.26 days; p less than 0.01), and drain removal occurred earlier (4.09 ± 1.25 vs. 4.60 ± 1.26 days; p less than 0.01). The difference in the time to return of bowel sounds was not statistically significant, however ($p = 0.29$). There were fewer overall postoperative complications in Group I compared to Group II (6.4% vs. 14.5%, $p = 0.04$).

Conclusion: Intra-operative peritoneal lavage with super-oxidized solution, as an adjunct to normal saline, resulted in better bacterial clearance at selected perforation sites, reduced wound infections and postoperative complications, and improved postoperative recovery. SOS may thus be a useful addition to the surgical treatment of peritonitis.

Key Words: *Peritonitis; Super-oxidized solution; Normal saline; Peritoneal lavage; Bacterial growth; Surgical site infection; Postoperative complications.*

INTRODUCTION

Peritonitis is an inflammation of the peritoneum that can occur after a bacterial infection, chemical irritation, or injury to the abdominal cavity. It continues to be an important surgical emergency, as delayed diagnosis and treatment would lead to sepsis, multiorgan dysfunction, and death (1). Secondary peritonitis is seen most often after the rupture of a hollow organ

in the abdomen, with the gastrointestinal contents and microorganisms entering the normally sterile peritoneal cavity (2). The prognosis depends on the underlying cause, degree of contamination, patient's physiological status, and the quality of the surgical treatment (3). The most common causes of acute peritonitis are perforated peptic ulcer, appendicular perforation, perforation of the intestine, and other intra-abdominal infections (4). There may be diagnostic difficulties, systemic complications, and high mortality in severe cases, especially if treatment is delayed (5). Peritonitis may also be caused by pelvic inflammatory and other gynecological diseases; however, gastrointestinal perforation is one of the most common causes of surgically induced secondary peritonitis (6). Early recognition, appropriate antimicrobial therapy, and timely surgical source control are essential to management (7). The clinical burden of peritonitis is different in different clinical settings and patient groups. Patients with cirrhosis/ascites frequently develop spontaneous bacterial peritonitis (SBP), which is an important complication (8). Peritoneal dialysis-related peritonitis is also a unique clinical entity and is a significant source of morbidity among renal failure patients (9,10). However, secondary peritonitis after gastrointestinal perforation is a surgical emergency that is still associated with a high postoperative mortality and morbidity rate (11,12). The clinical picture and etiology of secondary peritonitis in India can be different depending on the disease pattern in different regions of the country and the prevalence of gastrointestinal infections (13). Septic shock makes the management more complicated and increases the likelihood of adverse outcomes (14). Treatment of secondary peritonitis is mainly directed toward definitively treating the underlying condition, source control, antimicrobial therapy, and supportive measures. Intra-operative peritoneal lavage is often done to remove pus and infected material and other contaminants from the peritoneal cavity. Normal saline is available and physiologically compatible, and its action is mainly mechanical, but some controversy exists regarding the effectiveness of routine lavage in preventing postoperative complications (15,16). Super-oxidized solution (SOS) is now being considered as an alternative or addition to the lavage due to its antimicrobial action. It is formed by electrochemical activation and consists of reactive oxygen and chlorine species that have antimicrobial activity against various microorganisms, such as hypochlorous acid. This has led to its exploration for use in intra-operative peritoneal lavage, in the fields of wound management and infected surgical fields. As yet, however, the clinical evidence available is limited, and the comparative efficacy of SOS and normal saline in patients with proven peritonitis needs to be assessed further. In the present study, intra-operative peritoneal lavage using SOS and normal saline in patients undergoing surgery for peritonitis was compared. The main objective was to assess the comparative efficacy of the two methods, and the secondary objective was to assess the postoperative complications and recovery. Postoperative bacterial load, wound infection, wound- related symptoms, removal of the drain, return of bowel sounds, and hospital stay were evaluated.

MATERIALS AND METHODS

Study Design and Setting

This prospective, randomized, comparative single blind study was carried out in the Department of General Surgery, Geetanjali Medical College and Hospital (GMCH), Udaipur, India. The study aimed to evaluate and compare the outcome of intraoperative peritoneal lavage with super-oxidized solution (SOS) versus normal saline (NS) in patients with surgical peritonitis.

Study Population

The study focused on 220 patients with surgical peritonitis admitted through the outpatient department (OPD), inpatient department (IPD), or Emergency Department of GMCH, Udaipur. Patients were screened for eligibility using the pre-defined inclusion and exclusion criteria.

Inclusion Criteria

1. Patients admitted through OPD/IPD with a peritonitis diagnosis who needed surgical intervention.
2. Patients aged above 18 years.

Exclusion Criteria

1. Patients with multiple traumas, cardiopulmonary compromise, liver failure, or renal disease.
2. Patients reluctant to participate in the study.
3. Patients with a gynecological etiology of peritonitis.
4. Patients with a history of allergy to any of the study substances.

Sample Size and Group Allocation

A total of 220 eligible patients were included and randomly divided into two groups (110 patients per group):
Patients who underwent operation and irrigation of the peritoneum with super-oxidized solution (SOS) were assigned to Group I (n = 110). In Group II, the normal saline group (n = 110), patients had normal saline lavage during the operation. The sample size was determined based on the number of eligible patients available during the study period, and all eligible patients meeting the inclusion/exclusion criteria were enrolled.

Intervention and Operative Procedure

Patients with a diagnosis of peritonitis and who presented to the Surgery/Gastro-surgery outpatient department or the Emergency Department (ED) were evaluated for inclusion. After definitive surgery, the patients underwent peritoneal lavage as per the study group.

In Group I, 1 L of normal saline was initially irrigated into the peritoneum, followed by instillation of 200mL of SOS, which was prepared by diluting 100mL of SOS with normal saline to a final volume of 200mL. Group II received 1 L of normal saline into the peritoneal cavity followed by 200 mL of normal saline. Drains were inserted and clamped for one hour to ensure that the solution stayed in the peritoneum. The abdomen was then closed.

Postoperative Management and Microbiological Assessment

All patients were given postoperative antibiotic therapy of ceftriaxone, amikacin, and metronidazole. Patients with tubercular pyoperitoneum were also given anti-tubercular medicine as per renal status. On the third postoperative day, drain-fluid samples were taken in sterile vials and submitted to the Department of Microbiology for culture.

Samples were plated onto MacConkey's agar and blood agar, and then incubated at 37°C for 18 hours. Microbial growth was determined by Gram staining and biochemical tests in the cases that exhibited growth. Antibiotic susceptibility testing and estimation of the colony count were then carried out. The output of each drain and the nature of the drainage (serous or purulent) was noted daily. In case of a small output (<50 mL), the fluid was serous, drains were removed. For those who had two drains, the removal day for each drain was documented individually.

Clinical Assessment and Outcome Measures

The serum electrolytes and routine laboratory investigations such as total leucocyte count (TLC) and differential leucocyte count (DLC) were performed. Bowel sounds were clinically assessed by using a stethoscope just to the right of the umbilicus and were considered recovered when the sounds returned. Return of bowel sounds was recorded when 3–4 bowel sounds per minute were auscultated. Postoperative fever was also noted, as well as the duration of the fever. The patients were followed for any complications that occurred after surgery, such as superficial surgical site infection, burst abdomen, and fecal fistula. Other parameters recorded were duration of nil per oral status, hospital stay, drain removal time, and day of stitch removal. The main outcome measures were complications related to SOS and normal saline lavage. The demographic data of the two study groups were also analyzed as to whether they were associated with postoperative complications. Observations were made on a structured proforma that was then collated for statistical analysis.

Statistical Analysis

Data were initially entered into Microsoft Excel and later analyzed using IBM SPSS Statistics version 26. Quantitative variables were presented as mean ± standard deviation (SD) when normally distributed. Qualitative variables were presented as frequencies, proportions, ratios, and percentages. Continuous variables were compared between the two groups using an unpaired t-test, and associations between categorical variables were assessed using the chi-square test.

Ethical Considerations

The study was reviewed and approved by the Institutional Research Review Committee (IRRC), Geetanjali Medical College and Hospital, Udaipur (Reference No. GMCH/IRRC/PG23/2024/1101; approval meeting held on 13 March 2024), and the Human Research Ethics Committee (HREC), Geetanjali University, Udaipur (approval meeting held on 27 April 2024). Written informed consent was obtained from all participants before their inclusion in the study.

RESULTS

A total of 220 patients with peritonitis were included in the study and randomly allocated into two groups of 110 patients each. Group I received intraoperative peritoneal lavage with super-oxidized solution (SOS) following normal saline irrigation, whereas Group II received normal saline lavage alone. The results were compared with respect to baseline characteristics, postoperative bacterial load, wound-related outcomes, recovery parameters, and postoperative complications.

1. Baseline Demographic and Clinical Characteristics

The age distribution of patients was similar in both groups. In Group I, the most common age group was 31-45 years with 35 patients, and in Group II, the most common age group was 18-30 years with 32 patients. There was no statistical difference between the age distribution (χ^2=6.78, p=0.14). There were more males than females in both groups, 77 (70.0%) patients in Group I and 72 (65.5%) patients in Group II. There was no significant difference between genders (χ^2=0.51, p=0.47). Gastric perforation was the most common site in both groups, with 42 patients in Group I and 45 patients in Group II, followed by ileal perforation with 29 patients in Group I and 27 patients in Group II. There were no significant differences between the groups in terms of the distribution of perforation sites (χ^2=0.75, p=0.90).

Table 1. Baseline demographic and clinical characteristics of the study participants

Characteristic	Group I (n=110)	Group II (n=110)	p-value
Age group (years)			0.14
18–30	29	32	

31–45	35	30	
46–60	25	19	
61–75	18	17	
>75	3	12	
Gender			0.47
Male	77 (70.0%)	72 (65.5%)	
Female	33 (30.0%)	38 (34.5%)	
Site of perforation			0.90
Appendicular	7	5	
Colonic	9	11	
Duodenal	11	10	
Gastric	42	45	
Ileal	29	27	
Jejunal	10	10	
Primary peritonitis	2	2	

2. Comparison of Postoperative Bacterial Load

In the comparison of bacterial load immediately after surgery, there was a statistically significant difference between the two groups in patients with gastric perforation (p=0.01). In this subgroup, 26 patients in Group I did not have detectable growth of bacteria, while 18 patients in Group II did not have detectable bacteria. In Group II, there was heavy bacterial growth in 8 patients and in Group I there was heavy bacterial growth in 2 patients. There were no statistically significant differences with regard to appendicular (p=0.09), colonic (p=0.76), duodenal (p=0.50), jejunal (p=0.32) or ileal perforations (p=0.51). Patients that had gastric (p=0.01), jejunal (p=0.02) and ileal perforation (p=0.03) had statistically significant differences at 72 hours after surgery. In Group I, 31 patients had no growth of bacteria while in Group II, 22 of the patients had no growth of bacteria. In jejunal perforations, the bacterial growth was not detected in 8 patients of Group I in contrast to 3 patients of Group II. The same was true for 10 patients in Group I and 3 patients in Group II with ileal perforations, in whom no bacteria were found. No significant differences were found for appendicular (p=0.09), colonic (p=0.42), duodenal (p=0.40) or primary peritonitis (p=0.24).

Table 2. Site-wise comparison of bacterial load immediately after surgery and at 72 hours

Site of perforation	Immediate postoperative p-value	No growth at 72 hours: Group I	No growth at 72 hours: Group II	72-hour p-value
Appendicular	0.09	4	0	0.09
Colonic	0.76	4	3	0.42
Duodenal	0.50	6	2	0.40
Gastric	0.01	31	22	0.01
Ileal	0.51	10	3	0.03
Jejunal	0.32	8	3	0.02
Primary peritonitis	Not applicable	1	0	0.24

The p-values represent comparisons of the overall bacterial-load distributions between groups at each time point. The no-growth columns show the number of patients without detectable bacterial growth at 72 hours.

3. Postoperative Wound-Related Outcomes

In Group I, postoperative wound infection was seen in 30 (27.3%) patients, while in Group II, 45 (40.9%) patients had postoperative wound infection. This difference was found to be statistically significant (χ^2=8.46, p=0.003). The severity of the wound infection was significantly different between groups when evaluated site-wise, for duodenal (p=0.02), gastric (p<0.01), ileal (p=0.04) and jejunal (p=0.02) perforations. There were no significant differences in appendicular (p=0.51) or colonic perforations (p=0.17). In Group I, 30 (27.3%) patients and in Group II, 70 (63.6%) patients experienced postoperative wound pain. This difference was extremely statistically significant (χ^2=62.85, p<0.01). As far as wound-site discharge was concerned, 70 patients in Group I had no discharge while 40 patients in Group II did. 25 patients in Group I and 63 patients in Group II had purulent discharge, and 15 and 7 patients had serous discharge, respectively. The overall difference in pattern of discharge was statistically significant (χ^2=27.5, p<0.01).

Table 3. Comparison of postoperative wound-related outcomes

Outcome	Group I (n=110)	Group II (n=110)	Test statistic	p-value
Postoperative wound infection				

Present	30 (27.3%)	45 (40.9%)	χ^2=8.46	0.003
Absent	80 (72.7%)	65 (59.1%)		
Postoperative wound pain				
Present	30 (27.3%)	70 (63.6%)	χ^2=62.85	<0.01
Absent	80 (72.7%)	40 (36.4%)		
Wound-site discharge			χ^2=27.5	<0.01
Serous	15	7		
Purulent	25	63		
Nil	70	40		

4. Postoperative Recovery and Complications

The mean length of hospital stay in Group I was 8.98 ± 1.30 days and in Group II was 9.60 ± 1.26 days. The difference was statistically significant (p<0.01). Likewise, the mean day for the drainage to be removed was significantly earlier in Group I (4.09 ± 1.25 days) than in Group II (4.60 ± 1.26 days; p<0.01). The mean time for the return of bowel sounds was 4.13 ± 0.83 days in Group I and 4.25 ± 0.84 days in Group II. Bowel sounds were heard a little sooner in Group I, but this difference was not statistically significant (p=0.29). As for any complication that occurred in individual patients, wound dehiscence was observed in 4 patients of Group I and 8 patients of Group II. No patients in Group I and 2 patients of Group II required re-exploration. Incisional hernias were observed in 3 patients in each group, and no deaths were recorded in Group I, while 3 deaths were observed in Group II. Overall, 7 patients from Group I and 16 patients from Group II had postoperative complications that were observed (6.4% vs. 14.5%). This was statistically significant (χ^2=3.93, p=0.04).

Table 4. Comparison of postoperative recovery parameters and complications

Parameter	Group I (n=110)	Group II (n=110)	p-value
Recovery parameters			
Duration of hospital stay (days), mean ± SD	8.98 ± 1.30	9.60 ± 1.26	<0.01
Average day of drain removal, mean ± SD	4.09 ± 1.25	4.60 ± 1.26	<0.01
Return of bowel sounds (days), mean ± SD	4.13 ± 0.83	4.25 ± 0.84	0.29
Individual postoperative complications			
Wound dehiscence	4	8	Not reported
Re-exploration	0	2	Not reported
Incisional hernia	3	3	Not reported
Death	0	3	Not reported
Overall postoperative complications			
Present	7 (6.4%)	16 (14.5%)	0.04
Absent	103 (93.6%)	94 (85.5%)	

SD: Standard deviation.

Overall, patients who received super-oxidized solution for intraoperative lavage had fewer postoperative wound infections, wound pain, purulent discharge, earlier removal of drains, and shorter hospital stay. Overall rate of postoperative complications was also significantly reduced in this group. The difference in the return of bowel sounds was not statistically significant, however.

DISCUSSION

In the present study, intra-operative peritoneal lavage with super-oxidized solution was compared to normal saline in 220 patients with peritonitis who were divided into two study arms with 110 patients in each arm. There were no differences between the groups in terms of baseline characteristics, such as age, gender, and site of perforation. This comparability allows the differences seen in postoperative results to be interpreted, but may also be affected by disease- and patient-related factors.

The microbiological results showed the variations in the growth of the bacteria at the selected anatomical sites. The distributions of bacterial load were comparable for most of the perforation sites immediately after surgery, and different for gastric perforations. After 72 hours, the growth of bacteria in the gastric, ileal, and jejunal perforations was significantly lower in the SOS group. The results indicated that saline might have a mechanical cleansing effect, and SOS might offer an extra antimicrobial effect. Differences were, however, not uniform at all anatomical sites, and hence the results presented should be interpreted accordingly with the site and degree of contamination.

A significantly lower incidence of postoperative wound infection was seen in the SOS group compared to the normal saline group (27.3% vs. 40.9%, respectively; p=0.003). Additionally, the SOS group had less frequent purulent wound discharge (27.3% vs. 63.6%, p<0.01) and less wound pain (p<0.01). These results suggest an improvement in wound-related outcomes in patients who were treated with SOS. The present study does not determine the mechanism for the differences, but the antimicrobial properties of super-oxidized solution may explain these observations.

The use of SOS for intra-operative peritoneal lavage for peritonitis has also been previously compared (17). The site of the appendix (peritoneum) combined with the wound (during the surgery) provides more clinical background to the possible anti-SSI effects of SOS as a treatment for perforated appendicitis, as demonstrated in a randomized clinical trial (18). The use of SOS during the peritoneal lavage for peritonitis has also been explored in earlier studies (19,20). Those differences in the design of the studies, patient populations, operative procedures, and lavage protocols should be taken into consideration when comparing those findings with the present study.

The recovery after surgery was relatively good in the SOS group. This group had a significantly shorter duration of hospitalization than the normal saline group (8.98 ± 1.30 days versus 9.60 ± 1.26 days, respectively; p<0.01). Similarly, the mean day of drain removal was earlier in the SOS group (4.09 ± 1.25 versus 4.60 ± 1.26 days; p<0.01). The differences might be associated with the reduced incidence of wound infection and purulent drainage in this group. However, there was no significant difference between groups in terms of the mean time to return of bowel sounds (4.13 ± 0.83 days vs. 4.25 ± 0.84 days; p=0.29), suggesting that the other aspects of recovery did not significantly differ between the groups.
The total proportion of postoperative complications was significantly reduced in the SOS group compared to the normal saline group (6.4% vs. 14.5%, p=0.04). The incidence of wound dehiscence, re-exploration, and mortality was numerically lower in the SOS group, but not reported as being statistically significant when compared individually. Combined, the lower overall complication rates and better wound-related outcomes indicate possible benefits for the use of SOS in addition to traditional saline irrigation. However, the results do not constitute proof of an absolute decrease in each post-operative complication.

The present study has several limitations. The study was performed at a single tertiary care center, which may limit the generalizability of the findings to other healthcare settings. The operating surgeon was aware of group allocation, and this may have introduced some procedural or assessment bias. No formal sample-size calculation was reported. Long-term outcomes were not assessed. Furthermore, only the postoperative course was followed up, and outcomes such as late intra-abdominal complications and long-term recovery were not addressed. Further multicenter randomized controlled studies with larger patient populations, standardized intervention protocols and longer follow-up are needed to determine the role of SOS in routine intra-operative peritoneal lavage.

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