

Research Article

A Comparison of Warm Saline and Metronidazole Peritoneal Lavage for Wound-Healing Outcomes in Patients Undergoing Emergency Laparotomy

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Abstract: **Introduction:** Peritoneal contamination during emergency laparotomy increases the risk of postoperative surgical-site infection and delayed recovery. Antimicrobial lavage may provide additional benefit over saline irrigation alone. **Objective:** To compare warm saline and metronidazole peritoneal lavage in patients undergoing emergency laparotomy. **Methods:** This prospective comparative interventional study included 144 adults allocated equally to warm saline lavage or metronidazole lavage. The primary outcome was surgical-site infection within 30 days. Secondary outcomes included postoperative ileus, bacterial-load reduction, time to first flatus, postoperative pain, and hospital stay. **Results:** Surgical-site infection occurred in 24/72 patients (33.3%) in the saline group and 8/72 (11.1%) in the metronidazole group (RR 0.33, 95% CI 0.16–0.69; $p=0.003$). Metronidazole lavage produced a greater mean $\log_{10}$ bacterial reduction than saline (0.537 vs 0.367; mean difference 0.171, $p<0.001$). Time to first flatus was shorter by 8.78 hours ($p=0.011$), and hospital stay was reduced by 1.14 days ($p<0.001$). Postoperative ileus was less frequent with metronidazole, although not statistically significant. Pain scores were similar. **Conclusion:** Metronidazole peritoneal lavage reduced surgical-site infection and improved postoperative recovery compared with warm saline lavage.

Keywords: metronidazole; peritoneal lavage; emergency laparotomy; surgical-site infection; wound healing

INTRODUCTION

Emergency laparotomy is commonly performed for perforation peritonitis, intestinal obstruction, bowel ischemia, trauma, and other life-threatening intra-abdominal conditions. These patients often present with sepsis, heavy bacterial contamination, physiological compromise, and limited opportunity for preoperative optimization, resulting in a high risk of surgical-site infection, wound dehiscence, prolonged hospitalization, and mortality [1–3].

Successful postoperative wound healing depends on effective source control, removal of devitalized tissue, systemic antimicrobial therapy, and reduction of residual intra-abdominal contamination. Warm normal saline is widely used for peritoneal lavage because it is inexpensive, readily available, isotonic, and non-irritating. Its effect, however, is primarily mechanical, and evidence for routine saline lavage in abdominal sepsis remains inconclusive [4–6].

Metronidazole provides potent anaerobic coverage against organisms commonly implicated in polymicrobial peritonitis and intra-abdominal abscess formation [7]. When added to lavage fluid, it may reduce the residual microbial burden more effectively than saline alone and complement systemic antibiotics. Clinical studies have reported favourable outcomes with

metronidazole or other antimicrobial lavage solutions, including lower wound-infection and intra-abdominal abscess rates, although available evidence is limited by heterogeneous protocols, small samples, and variation in underlying pathology [8,9].

A direct comparison between warm saline and metronidazole lavage is therefore clinically relevant, particularly in emergency surgery and resource-limited settings where postoperative wound complications substantially increase morbidity and cost. The present study was undertaken to compare the wound-healing efficacy of warm saline and metronidazole peritoneal lavage in patients undergoing emergency laparotomy, with particular emphasis on surgical-site infection, wound dehiscence, and overall postoperative wound recovery.

Objectives

The primary objective was to compare warm saline and metronidazole peritoneal lavage for prevention of surgical site infection within 30 days after emergency laparotomy. The secondary objective was to compare the incidence of postoperative ileus between the two lavage strategies. Prespecified supportive outcomes were the change in peritoneal bacterial load, time to first flatus, postoperative pain, and duration of hospital stay.

MATERIALS AND METHODS

Study design and participants

This prospective, parallel-group comparative interventional study was conducted in the Department of General Surgery at Vydehi Institute of Medical Sciences and Research Centre, Bengaluru, India. Adults undergoing emergency laparotomy for intra-abdominal pathology with peritoneal contamination were enrolled after written informed consent. Patients with diabetes mellitus, cirrhosis, chronic kidney disease, or current systemic corticosteroid therapy were excluded. Participants were allocated in a 1:1 ratio to warm saline lavage or metronidazole lavage. The planned sample was 144 participants (72 per group), based on 80% power, a two-sided alpha of 0.05, and allowance for attrition.

Interventions and perioperative procedures

After induction of general anaesthesia and entry into the peritoneal cavity, the source and degree of contamination were recorded. A 2-mL peritoneal-fluid specimen was collected aseptically before lavage, after which definitive source-control surgery was completed according to the underlying pathology. In the warm saline group, the peritoneal cavity was irrigated with 2 L of sterile 0.9% saline warmed to approximately body temperature. In the metronidazole group, 1 g metronidazole diluted in warm 0.9% saline to a total volume of 2 L was used. The lavage solution was distributed throughout all abdominal quadrants and removed by suction. A second 2-mL specimen was collected immediately after lavage, and primary skin closure was performed in all participants.

Perioperative care followed the institutional emergency-laparotomy protocol. Broad-spectrum systemic antibiotics were initiated before surgery and continued postoperatively, with subsequent modification according to microbiological findings and clinical response. Fluid and electrolyte management, analgesia, nasogastric decompression, and advancement of oral intake were determined by the treating surgical team.

Microbiological assessment

Pre- and post-lavage specimens were transported promptly to the microbiology laboratory. Quantitative bacterial burden was reported as colony-forming units per millilitre (CFU/mL), and organisms were identified

using standard Gram staining, culture, and biochemical methods. Participant-level microbiological efficacy was expressed as log₁₀(pre-lavage CFU/post-lavage CFU).

Outcomes and follow-up

The primary outcome was SSI within 30 postoperative days, assessed during hospitalization and follow-up using criteria aligned with the Centers for Disease Control and Prevention definition. SSI was identified by purulent drainage, a positive culture, or compatible local inflammatory findings involving the incision or deeper operative tissues. The secondary outcome was postoperative ileus, assessed clinically during daily postoperative review. Time to first passage of flatus was recorded separately. Additional outcomes were immediate and 2-hour postoperative pain on a 10-point visual analogue scale, post-lavage bacterial burden, log₁₀ bacterial reduction, and postoperative length of stay.

Statistical analysis

Continuous variables were summarized as mean (SD) or median (IQR), and categorical variables as n (%). Between-group comparisons used Welch's t test or the Mann-Whitney U test, as appropriate; categorical variables were compared using the Pearson chi-square test with continuity correction for 2 x 2 tables or Fisher's exact test when expected counts were small. Within-group change in CFU/mL was assessed using the Wilcoxon signed-rank test, and between-group microbiological efficacy using participant-level log₁₀ reduction. Binary outcomes were reported as risk ratios and risk differences, and continuous outcomes as mean differences, each with 95% confidence intervals. Tests were two-sided with p<0.05 considered significant. No outcome data were missing. Analyses were performed using IBM SPSS Statistics version 22.0.

Ethics

The study was approved by the Institutional Ethics Committee of Vydehi Institute of Medical Sciences and Research Centre. Written informed consent was obtained from each participant or a legally authorized representative, and study records were coded to maintain confidentiality.

RESULTS

Study population

All 144 participants were included in the analysis: 72 received warm saline lavage and 72 received metronidazole lavage. Follow-up through postoperative day 30 was complete. Participant, operative, and intraoperative contamination characteristics are summarized in Table 1.

Microbiological response

Escherichia coli was the most frequently identified pre-lavage organism in both groups. Pre-lavage bacterial loads were comparable. Bacterial counts decreased significantly after lavage within each group, with a greater log10 reduction after metronidazole lavage (Table 2 and Figure2).

Clinical outcomes

Surgical site infection within 30 days occurred in 24 (33.3%) participants in the warm saline group and 8 (11.1%) in the metronidazole group, corresponding to a risk ratio of 0.33 (95% CI 0.16-0.69; $p=0.003$). Postoperative ileus occurred in 18 (25.0%) and 9 (12.5%) participants, respectively; this difference was not statistically significant (RR 0.50, 95% CI 0.24-1.04; $p=0.088$) (Table 3 and Figure 1).

The metronidazole group had an earlier return of bowel function and a shorter postoperative hospital stay. Immediate and 2-hour postoperative pain scores did not differ significantly between groups (Table 3).

TABLES

Table 1. Participant, operative, and contamination characteristics

Characteristic	Warm saline (n=72)	Metronidazole (n=72)	Test statistic	p-value
Age, years, mean $\pm$ SD	41.82 $\pm$ 11.95	42.25 $\pm$ 13.43	Welch $t=0.20$; $df=140.1$	0.839
Male sex, n (%)	46 (63.9%)	37 (51.4%)	$\chi^2=1.82$; $df=1$	0.177
Any recorded comorbidity, n (%)	12 (16.7%)	10 (13.9%)	$\chi^2=0.05$; $df=1$	0.817
Indication for laparotomy, n (%)			$\chi^2=10.90$; $df=5$	0.053
Acute appendicitis (perforated)	23 (31.9%)	38 (52.8%)		
Intestinal obstruction	17 (23.6%)	14 (19.4%)		
Peptic ulcer perforation	7 (9.7%)	7 (9.7%)		
Perforation peritonitis	11 (15.3%)	3 (4.2%)		
Strangulated hernia	6 (8.3%)	7 (9.7%)		
Typhoid ileal perforation	8 (11.1%)	3 (4.2%)		
Intraoperative contamination, n (%)			$\chi^2=1.22$; $df=2$	0.543
Feculent	16 (22.2%)	16 (22.2%)		
Purulent	45 (62.5%)	40 (55.6%)		
Serous	11 (15.3%)	16 (22.2%)		
Operative time, min, mean $\pm$ SD	114.14 $\pm$ 24.44	105.96 $\pm$ 25.67	Welch $t=-1.96$; $df=141.7$	0.052

Values are mean $\pm$ SD or n (%). Group comparisons used Welch t tests for continuous variables and chi-square tests for categorical variables; continuity correction was applied to 2 $\times$ 2 comparisons.

Table 2. Microbiological findings and bacterial-load response to peritoneal lavage

Variable	Warm saline (n=72)	Metronidazole (n=72)	Effect estimate (95% CI)	Test statistic	p-value
Pre-lavage organism, n (%)				$\chi^2=4.21$; $df=6$	0.648
<i>Bacteroides fragilis</i>	8 (11.1%)	6 (8.3%)			
<i>Enterococcus faecalis</i>	5 (6.9%)	5 (6.9%)			
<i>Escherichia coli</i>	29 (40.3%)	22 (30.6%)			
<i>Klebsiella pneumoniae</i>	16 (22.2%)	15 (20.8%)			
No growth	7 (9.7%)	12 (16.7%)			
<i>Pseudomonas aeruginosa</i>	2 (2.8%)	5 (6.9%)			
<i>Streptococcus</i> spp.	5 (6.9%)	7 (9.7%)			
Pre-lavage CFU/mL, median (IQR)	306,447 (187,774-518,244)	347,814 (226,053-625,574)	—	Mann-Whitney $U=2300$	0.244
Post-lavage CFU/mL, median (IQR)	136,724 (71,826-237,304)	96,068 (59,916-187,693)	—	Mann-Whitney $U=2192$	0.110
Log10 bacterial reduction, mean $\pm$ SD	0.367 $\pm$ 0.128	0.537 $\pm$ 0.131	MD 0.171 (0.128-0.213)	Welch $t=7.92$; $df=141.9$	<0.001

CFU, colony-forming units; CI, confidence interval; IQR, interquartile range; MD, mean difference. The mean difference is metronidazole minus warm saline. Within-group pre-to-post reductions were significant for both warm saline (Wilcoxon $W=0$; $p<0.001$) and metronidazole (Wilcoxon $W=0$; $p<0.001$).

Table 3. Primary, secondary, and postoperative recovery outcomes

Outcome	Warm saline (n=72)	Metronidazole (n=72)	Effect estimate (95% CI)	Test statistic	p-value
Surgical site infection within 30 days, n (%)	24 (33.3%)	8 (11.1%)	RR 0.33 (0.16-0.69) RD -22.2% (-35.3% to -9.1%)	$\chi^2=9.04$; df=1	0.003
Postoperative ileus, n (%)	18 (25.0%)	9 (12.5%)	RR 0.50 (0.24-1.04) RD -12.5% (-25.1% to 0.1%)	$\chi^2=2.92$; df=1	0.088
Time to first flatus, h, mean $\pm$ SD	71.97 $\pm$ 20.69	63.19 $\pm$ 20.18	MD -8.78 (-15.51 to -2.05)	Welch t=-2.58; df=141.9	0.011
Hospital stay, d, mean $\pm$ SD	7.68 $\pm$ 1.78	6.53 $\pm$ 1.56	MD -1.14 (-1.70 to -0.59)	Welch t=-4.10; df=139.6	<0.001
Immediate postoperative VAS, median (IQR)	7.00 (6.17-7.90)	6.80 (5.95-7.43)	—	Mann-Whitney U=2303	0.249
VAS at 2 h, median (IQR)	5.85 (4.70-7.03)	5.35 (4.50-6.60)	—	Mann-Whitney U=2150.5	0.078

CI, confidence interval; IQR, interquartile range; MD, mean difference; RD, risk difference; RR, risk ratio; VAS, visual analogue scale. Binary outcomes were compared using continuity-corrected chi-square tests. Mean differences are metronidazole minus warm saline; negative values for recovery times favor metronidazole.

FIGURES

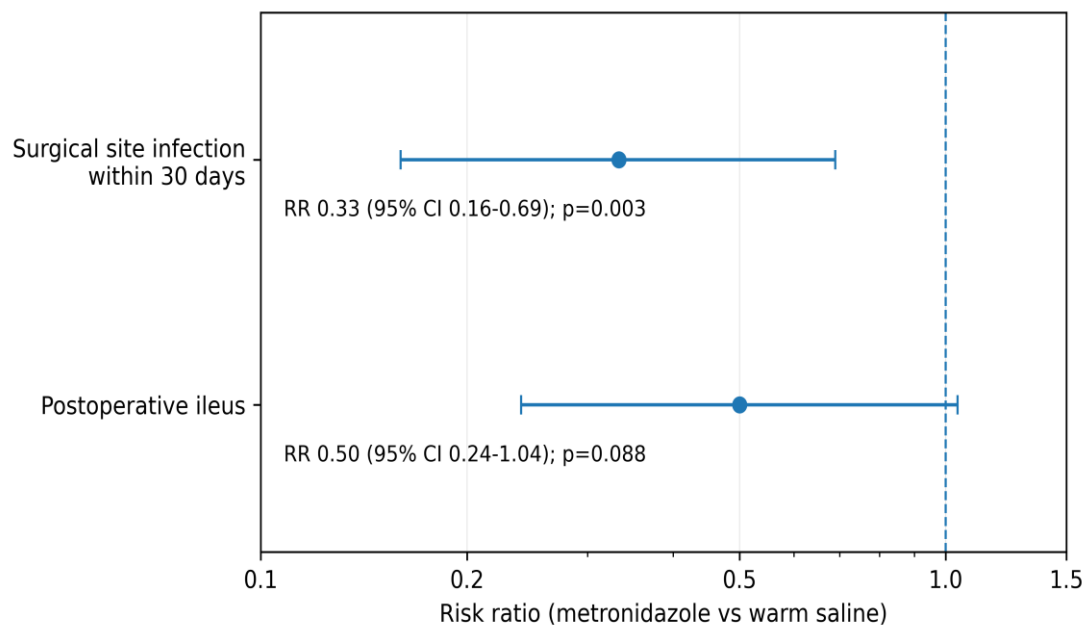


Figure 1. Risk ratios for the prespecified clinical outcomes. Values below 1 favor metronidazole lavage. Error bars represent 95% confidence intervals.

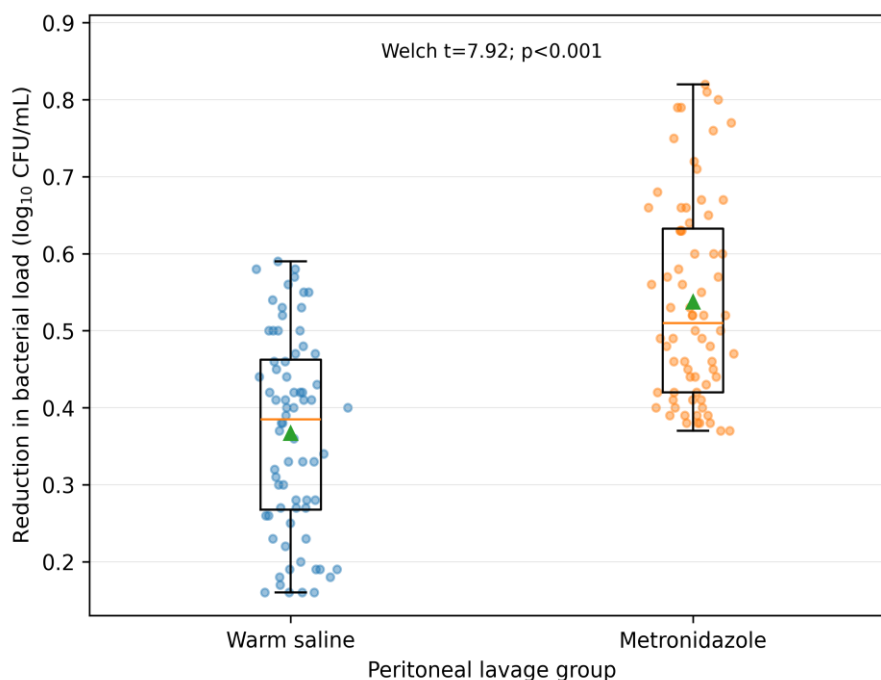


Figure 2. Distribution of log₁₀ bacterial-load reduction after peritoneal lavage. Boxes show the interquartile range, horizontal lines show medians, triangles show means, whiskers show the non-outlier range, and points represent individual participants.

DISCUSSION

In this prospective comparative study, metronidazole peritoneal lavage was associated with better microbiological and clinical outcomes than warm saline lavage after emergency laparotomy. The 30-day surgical-site infection rate was reduced from 33.3% with saline to 11.1% with metronidazole, corresponding to a 67% relative risk reduction and an absolute reduction of 22.2 percentage points. Metronidazole lavage also produced a greater mean log₁₀ reduction in bacterial burden, earlier passage of flatus by approximately 9 hours, and a 1.14-day shorter hospital stay. Postoperative ileus was numerically less frequent, although the difference did not reach statistical significance, and postoperative pain was comparable between groups. The superiority of metronidazole over saline is biologically plausible because saline provides mechanical dilution without sustained antimicrobial activity. St Peter et al. randomized children with perforated appendicitis to irrigation or suction alone and found nearly identical intra-abdominal abscess rates of 18.3% and 19.1%, respectively. Hospital stay was also similar, and irrigation did not improve postoperative outcomes despite standardized operative management [10]. These findings suggest that saline irrigation alone may not meaningfully alter infection risk, whereas the present study demonstrated both a larger bacterial-load reduction and fewer incisional infections when an anaerobic agent was added.

Comparable findings were reported by Snow et al. in an adult randomized equivalence trial involving suppurative

or perforated appendicitis. Peritoneal irrigation and suction alone produced equivalent intra-abdominal abscess rates, with no clinically important advantage in secondary recovery outcomes [11]. This reinforces the distinction between simple lavage and antimicrobial lavage: dilution alone may be insufficient when residual organisms remain adherent to the peritoneum or wound surfaces.

The volume of lavage may also be less important than its composition. Mashbari et al. compared 5-, 10-, and 20-L intra-abdominal irrigation during emergency trauma laparotomy. Increasing irrigation volume did not reduce postoperative infection, and the 20-L group showed a trend toward more deep SSI than the 5- and 10-L groups. The authors therefore questioned the assumption that greater dilution necessarily improves outcomes [12]. In the present study, both groups received the same 2-L volume, allowing the observed difference to be attributed more directly to the addition of metronidazole rather than to lavage quantity.

Evidence with other antimicrobial solutions supports the principle that local antimicrobial activity may add value. Schneider et al. randomized children with localized appendicular peritonitis to taurolidine or saline lavage and monitored inflammatory markers and recovery during the first two postoperative weeks [13]. Although the sample was small, taurolidine lavage was feasible and did not produce major treatment-related toxicity. The study is relevant because it demonstrated that an antimicrobial lavage strategy can be delivered safely within contaminated abdominal surgery, although its

paediatric population and different agent limit direct comparison with our adult emergency-laparotomy cohort.

Liu et al. compared Dermacyn-based peritoneal irrigation with conventional lavage and reported reduced postoperative drainage, lower microbiological contamination, and fewer infective complications with the antimicrobial solution [14]. Peritoneal drainage decreased from approximately 30 mL to 5 mL between 24 and 72 hours in the intervention group, and no major safety concern was identified. These results parallel our findings of greater bacterial clearance and shorter hospitalization after metronidazole lavage, while also supporting the broader concept that antimicrobial irrigation may improve recovery when used after adequate source control.

However, pooled evidence concerning routine saline irrigation remains unfavourable. Hajibandeh et al. analysed three randomized trials and two observational studies including 2,511 patients undergoing emergency laparoscopic appendectomy. Irrigation did not reduce intra-abdominal abscesses, wound infection, or hospital stay; pooled estimates were OR 2.39 for abscess, risk difference 0.00 for wound infection, and mean difference -1.02 days for stay. Irrigation also prolonged operative time by approximately 7 minutes [15]. The present findings differ because metronidazole lavage significantly reduced SSI and hospital stay, suggesting that the antimicrobial component, rather than irrigation itself, may account for the benefit.

Burini et al. subsequently reviewed 17 comparative studies of aspiration versus lavage in complicated appendicitis. They found no significant reduction in postoperative abscess, reoperation, wound infection, or length of stay with irrigation, while suction-only approaches generally had shorter operative times [16]. Their review also highlighted concerns that lavage may spread contamination or dilute local immune mediators. Our microbiological data provide an important counterpoint: both solutions reduced bacterial counts, but metronidazole achieved a significantly greater log₁₀ reduction, suggesting that antimicrobial lavage may overcome some limitations of simple saline dilution.

Lee et al. evaluated 553 adults undergoing laparoscopic appendectomy, of whom 207 received irrigation and 346 suction alone. Irrigation was associated with longer operative time, a higher overall postoperative complication rate of 12.6% versus 4.5%, and remained an independent risk factor for SSI after adjustment [17]. Although this study involved uncomplicated appendicitis and was observational, it further cautions against assuming that routine saline irrigation is harmless or beneficial. In contrast, our participants had established peritoneal contamination, received equal lavage volumes, and showed a clear infection reduction with metronidazole.

The reduction in postoperative ileus from 25.0% to 12.5% did not achieve statistical significance, but the earlier return of flatus suggests a possible recovery benefit. Reduced residual bacterial burden and peritoneal inflammation may have contributed, although bowel handling, disease severity, electrolyte status, opioid exposure, and nasogastric management were not fully standardized. Similarly, the absence of a pain difference indicates that metronidazole lavage improved infective and recovery outcomes without an evident analgesic effect.

The study's strengths include equal group sizes, complete 30-day follow-up, standardized lavage volume, quantitative pre- and post-lavage cultures, and reporting of both relative and absolute treatment effects. Baseline contamination and bacterial burden were comparable, and the microbiological findings were directionally consistent with the clinical reduction in SSI.

Several limitations merit consideration. The single-centre design, non-blinded allocation, exclusion of selected high-risk patients, and limited power for uncommon complications may restrict generalizability. In addition, variation in operative pathology and postoperative management could have influenced outcomes.

CONCLUSION

Metronidazole peritoneal lavage produced greater bacterial-load reduction, a substantially lower 30-day SSI rate, earlier return of bowel function, and shorter hospitalization than warm saline lavage after emergency laparotomy. These findings support metronidazole lavage as a potentially useful adjunct after definitive source control, while larger randomized multicentre trials are required to confirm safety, reproducibility, and effectiveness across different causes and severities of peritoneal contamination.

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