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ORIGINAL ARTICLE

Saline solution vs. stabilized isotonic sodium hypochlorite lavage in complicated appendicitis: a comparative study

Milton Alberto Muñoz-Leija[1,4] · Marion Carolina Alemán-Jiménez[2] · Ramón González-Lemus[3] · Raúl Dario Martínez-Carvajal[1] · Saúl Tóvar-López[1] · Alejandro Quiroga-Garza[2] · Armando Magdaleno Joya-Munguía[4] · Heliodoro Plata-Álvarez[1]

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Abstract

Purpose There is no clear consensus on whether peritoneal lavage should be used in complicated appendicitis, nor which solution is ideal. This study evaluated the outcomes of two different intraperitoneal lavage solutions in adult patients with complicated appendicitis.

Methods We conducted a prospective analytical comparative study including adult patients with complicated appendicitis treated by open appendectomy between January 2023 and July 2024. Patients were allocated according to intraoperative availability of lavage solution to either saline solution (SS) lavage or stabilized isotonic sodium hypochlorite solution (SISHS) lavage. Primary outcomes were length of hospital stay, postoperative complications within 30 days, and total direct treatment costs.

Results A total of 120 patients were included (60 per group). Baseline demographic and clinical characteristics were comparable. Mean hospital stay was significantly shorter in the SISHS group compared with the SS group (1.86 ± 0.60 vs 6.15 ± 5.59 days; $p = 0.004$). Postoperative complications, including wound infection, seroma, abdominal wall abscess, intra-abdominal abscess, postoperative ileus, pain, and abdominal distension, were less frequent in the SISHS group (all $p < 0.05$). Reoperations were required in 21 patients in the SS group and in none of the SISHS group. Total direct treatment costs were 42.8% lower in the SISHS group.

Conclusion These findings suggest that SISHS lavage may offer favorable postoperative outcomes, including shorter hospital stays, lower complication rates, and reduced direct treatment costs in adult patients undergoing open appendectomy for complicated appendicitis. Further controlled studies are needed to confirm these findings.

Keywords Appendicitis · Intraperitoneal lavage · Saline solution & peritonitis

Background

Appendicitis is the leading cause of acute abdomen [1–3], with a lifetime incidence of 16% [4, 5] and a post-appendectomy mortality rate of less than 1% [6, 7]. It can present as localized or generalized, with 55% of cases being complicated (acute appendicitis accompanied by peritonitis, appendiceal rupture, gangrene, intra-abdominal abscess, intraperitoneal fecaliths, intraoperative mass, and/or purulent material within the cavity) [8, 9]. Without perforation, 5% of cases experience postoperative complications. In cases with perforation, over 50% develop postoperative complications, primarily surgical site infection, intra-abdominal abscess, abdominal wall abscess, necrotizing fasciitis, and paralytic ileus [10–12].

✉ Milton Alberto Muñoz-Leija
miltonalberto1994@gmail.com

1 General Surgery Department, Mexican Social Security Institute, Monterrey, México

2 School of Medicine, Autonomous University of Nuevo León, San Nicolás de los Garza, México

3 Bivium International, Inc., San Antonio, USA

4 General Surgery Department, Hospital Joya, Puerto Vallarta, México

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In cases of perforation, intraperitoneal lavage is commonly used, a practice described since the 20th century [13]. Saline solutions are routinely employed due to their availability, although other solutions like chlorhexidine gluconate or antibiotic dilutions have been reported by various authors, the use of these alternative solutions are controversial due to potential adverse effects such as the development of bacterial resistance [14]. In 2019, Gammeri et al. performed a secondary review and meta-analysis comparing isolated suction versus saline lavage effectiveness in complicated and uncomplicated appendicitis, associating lavage with reduced hospital stays and recommending studies with other solutions. [15] In 2023, Zou et al. conducted a systematic review and meta-analysis regarding saline intraperitoneal lavage for intraabdominal infections, determining very low-quality evidence and recommending further studies. [16] Given the controversy between potential adverse events and favorable outcomes reported with solutions for peritoneal lavage [14], recommendations from other authors to evaluate non-saline solutions [15], low-quality evidence from previous studies, and the necessity for additional research [16].

Stabilized isotonic sodium hypochlorite solution (SISHS) was selected because reduced-concentration hypochlorite formulations have demonstrated preserved bactericidal activity with markedly lower fibroblast and keratinocyte cytotoxicity compared with traditional antiseptics [17, 18]. SISHS is an isotonic, non-cytotoxic modified Dakin's solution with rapid broad-spectrum antimicrobial effects documented in regulatory evaluations [19, 20]. Clinical studies in wound management have further supported its biocompatibility and effective bioburden reduction [21]. In addition, this solution was incorporated into the official medical-supply formulary of the Instituto Mexicano del Seguro Social (IMSS) approximately five years ago and has since been routinely available in our institution, making it a practical and feasible candidate for evaluation in contaminated abdominal environments. These characteristics collectively justify the selection of SISHS as the intervention of interest in this study.

Objectives

Compare the results in terms of postoperative hospital stay (total days), rates of the postoperative complications (frequency and percentage) occurring within one month (30 days) and total direct treatment cost for each group. One group managed conventionally with saline solution lavage, referred to as the Saline Solution (SS) group and a second group treated with isotonic stabilized sodium hypochlorite solution lavage, designated as the SISHS group (Fig. 1).

Patients and materials

After obtaining approval from the corresponding institutional committees (R-2024-1912-028), a prospective analytical comparative study was conducted at Hospital General de Zona con Medicina Familiar No. 6, part of the Instituto Mexicano del Seguro Social (IMSS) in northeastern Mexico (Nuevo León Delegation). Follow-up evaluations were conducted at 7, 14 and 30 days postoperatively through medical interview, physical examination, and paraclinical tests when indicated.

Patients were allocated non-randomly according to real-time availability of the lavage solution in the operating

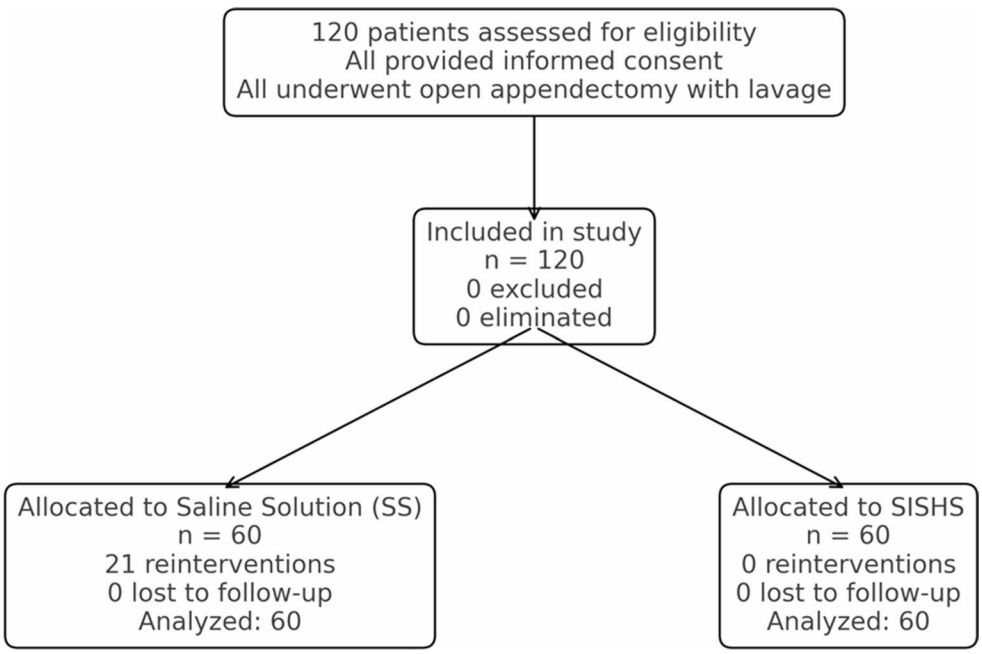


Fig. 1 Study flowchart. CONSORT-style flow diagram showing patient enrollment, allocation, follow-up, and analysis. SS: Saline Solution; SISHS: Stabilized Isotonic Sodium Hypochlorite Solution

room. This allocation process was not controlled or concealed and may introduce selection bias. Neither surgeons nor outcome assessors were blinded to group assignment due to the nature of the intervention.

Prior to surgery, all participants provided informed consent. Patients and their accompanying relative (serving as witness) received a detailed explanation of the procedure, its availability, benefits, alternatives, and potential complications. Emphasis was placed on the voluntary nature of participation, comprehension of all information provided, free choice, and the possibility of leaving the study at any time.

All procedures were carried out between January 2023 and July 2024. All data were anonymized prior to analysis.

Inclusion criteria.

- Patients ≥ 18 years of age.
- Signed informed consent.
- Diagnosis of complicated appendicitis.
- Treatment by open appendectomy.
- Complete clinical and follow-up information available.

Exclusion criteria.

- Patients < 18 years of age.
- Lack of informed consent.
- Alternative diagnosis.
- Surgical procedure other than open appendectomy.
- Incomplete clinical information.

Elimination criteria.

- Voluntary discharge.
- Loss to follow-up.

All patients underwent conventional open appendectomy via an infraumbilical midline incision (laparoscopy was not performed due to lack of supplies). All patients presented the same pattern of intraoperative severity, characterized by appendiceal perforation, presence of a fecalith, and purulent contamination of at least 100 milliliters.

All procedures were performed by board-certified general surgeons adhering to the same standardized operative protocol. All surgeons performed the appendectomy using the Pouchet technique with non-absorbable 2 − 0 silk suture. Although cases were not stratified by surgeon, the uniformity of both the operative approach and the surgical technique minimizes the impact of inter-surgeon variability.

In the SISHS group, after aspiration of purulent material and appendectomy, lavage was performed using 443 mL of stabilized isotonic sodium hypochlorite solution (SISHS). The solution remained in the abdominal cavity for 2 min before being completely suctioned. In the SS group, following aspiration and appendectomy, lavage was performed using 2,000 mL of saline solution (SS), maintained in the cavity for 3–5 min before suction.

All patients received preoperative antibiotic prophylaxis with ceftriaxone (1g) and metronidazole (750 mg). Antibiotic therapy continued during hospitalization until culture results of the purulent material became available, after which targeted therapy was initiated. A Penrose drain was placed in all patients.

A direct treatment cost analysis was performed comparing the SISHS and SS groups. Included cost components were hospital stay, surgical procedure, medications, medical supplies used during hospitalization, outpatient follow-up, and management of postoperative complications, including readmissions and re-interventions when applicable. Indirect or non-medical costs were not assessed. All cost data were obtained from the official institutional price lists of the IMSS corresponding to the study period and expressed in Mexican pesos (MXN). No currency conversion was applied.

Statistical analysis

Considering the characteristics of this study, sample size calculation was performed for cases and controls with a precision of 5 mm, statistical power of 90%, and two-tailed significance level (0.15). According to reported literature, the estimated prevalence of complications was 50% [10–12], resulting in an estimated minimum of 42 patients per group. However, it was decided to increase the sample size to 60 patients per group due to convenience and availability, utilizing a convenience sampling method. Statistical analysis was performed using a database created with Excel (version 2024) for iOS, subsequently analyzed using SPSS Statistics (version 24.1) for macOS. Absolute frequencies and proportions were reported for qualitative variables. The Kolmogorov–Smirnov test was applied to evaluate normality; means and standard deviations were calculated for parametric variables, and medians with interquartile ranges for non-parametric variables. Independent samples were analyzed using Student's t-test and the Mann–Whitney U test (for quantitative variables such as age, based on distribution of data). Qualitative variables were analyzed using Chi-square or Fisher's exact test. A p-value < 0.05 was considered statistically significant. No interim analyses were developed.

Results

A total of 120 patients were evaluated, with 60 patients in each group. Of the overall population, 58.33% were male. The mean age was 37.62 ± 14.75 years; the SS group had

Table 1 Descriptive profile of participants

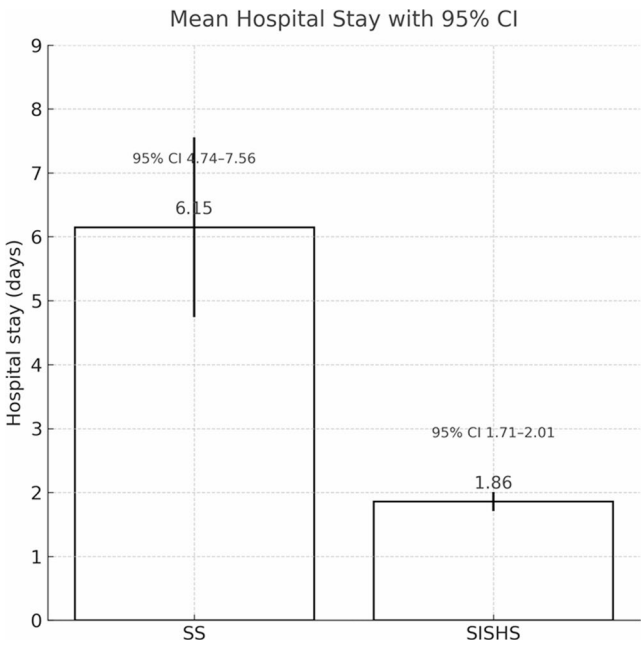
Variable	General	SS	SISHS	*P*
Gender (M/F)	M: 70 (58.33%)F: 50 (41.66%)	M: 36 (60%) F: 24 (40%)	M: 34 (56.67%) F: 26 (43.33%)	0.208 0.312
Age (years)	37.62 ± 14.75	39.28 ± 15.73	35.96 ± 13.77	0.889
Symptom duration (days)	2.70 ± 1.46	2.90 ± 1.19	2.81 ± 1.74	0.214
Medical history				
T2DM	33 (27.5%)	18 (30%)	15 (25%)	0.485
SAH	34 (28.3%)	14 (23.33%)	20 (33.33%)	0.194
HIV	1 (0.83%)	1 (1.67%)	0 (0%)	0.542
HTG	3 (2.5%)	1 (1.67%)	2 (3.33%)	0.590
PWE	1 (0.83%)	0 (0%)	1 (1.67%)	0.602
BMI (kg/m²)	30.14 ± 4.28	29.43 ± 4.11	30.8 ± 4.4	0.064

SS Saline Solution, *SISHS* Stabilized Isotonic Sodium Hypochlorite Solution, *M* Male, *F* Female, *T2DM* Type 2 Diabetes Mellitus, *SAH* Systemic Arterial Hypertension, *HIV* Human Immunodeficiency Virus, *HTG* Hypertriglyceridemia, *PWE* Person with Epilepsy, *BMI* Body Mass Index

Table 2 Percentage of complications at 30 days in both groups

Complication	General	SS	SISHS	*P*
Reintervention	21 (17.5%)	21 (35%)	0 (0%)	0.000*
Seroma	43 (35.83%)	30 (50%)	13 (21.67%)	0.001*
Abdominal Wall Abscess	20 (16.67%)	15 (25%)	5 (8.33%)	0.01*
Wound Infection	31 (25.8%)	22 (36.67%)	9 (15%)	0.02*
Abdominal Distension	46 (38.33%)	32 (53.33%)	14 (23.33%)	0.002*
Surgical Pain	30 (25%)	24 (40%)	6 (10%)	0.001*
Postoperative Ileus	25 (20.83%)	18 (30%)	7 (11.67%)	0.01*
Intra-abdominal Abscess	16 (13.33%)	16 (26.67%)	0 (0%)	0.001*

SS Saline Solution, *SISHS* Stabilized Isotonic Sodium Hypochlorite Solution



Graph 1 Difference in average hospital stay between the two groups. Mean postoperative hospital stay (days) in both treatment groups with 95% confidence intervals. SS: Saline Solution; SISHS: Stabilized Isotonic Sodium Hypochlorite Solution

a mean age of 39.28 ± 15.73 years, and the SISHS group 35.96 ± 13.77 years, with no statistically significant difference ($p = 0.889$). The average duration of symptoms prior to surgery was 2.70 ± 1.46 days, with no significant difference between groups ($p = 0.214$). The most frequent comorbidities were systemic arterial hypertension (28.3%) and type 2 diabetes mellitus (27.5%). The mean BMI of the study population was 30.14 ± 4.28 kg/m². No significant between-group differences were found in these baseline characteristics (Table 1).

Laboratory values showed no statistically significant differences between groups except for total bilirubin ($p = 0.001$), direct bilirubin ($p = 0.041$), and C-reactive protein ($p = 0.030$), all of which were higher in the SISHS group.

The overall mean length of hospital stay was 4.00 ± 3.09 days. The SS group had a mean stay of 6.15 ± 5.59 days, compared with 1.86 ± 0.60 days in the SISHS group, a statistically significant difference ($p = 0.004$) (Graph 1).

Postoperative complications were identified and classified using standard clinical and laboratory criteria during scheduled follow-up visits at 7, 14, and 30 days. All complications were evaluated and confirmed by the attending surgical team responsible for postoperative assessment.

No deaths occurred during the 30-day follow-up. A total of 21 patients in the SS group required reoperation for postoperative complications, whereas no reoperations were required in the SISHS group. Postoperative complications differed significantly between groups. The SISHS group exhibited lower frequencies of seroma ($p = 0.001$), abdominal wall abscess ($p = 0.010$), wound infection ($p = 0.020$), abdominal distension ($p = 0.002$), postoperative surgical pain ($p = 0.001$), postoperative ileus ($p = 0.010$), and intra-abdominal abscess ($p < 0.001$) (Table 2).

The total direct cost for the entire cohort ($n = 120$) was 8,453,916 MXN, whereas the SISHS group accounted for $4,835,024 MXN. The SISHS group generating 42.8% lower total direct treatment costs compared with the SS group.

Discussion

Intra-abdominal infections represent a common surgical emergency and a major cause of non-traumatic hospital mortality [22]. Optimal management relies on early diagnosis, prompt and adequate source control, appropriate antimicrobial therapy, and timely physiological stabilization when necessary [23]. In general surgery, the selective use of irrigation and drain placement may be beneficial under specific circumstances [24], however, despite multiple recommendations for managing intra-abdominal infections, the use of antiseptic solutions remains limited and debated due to concerns regarding potential tissue toxicity [25].

This study evaluated two commonly available intraperitoneal lavage strategies in a homogeneous adult population with standardized pathology—perforated appendicitis with purulent contamination. Strengths of this investigation include prospective follow-up, uniform intraoperative severity, a sample size exceeding the calculated minimum requirement, and comparison against the lavage solution most widely used in clinical practice (saline solution).

A principal limitation is the exclusive use of an open surgical approach, reflecting the predominant operative strategy in our clinical setting. Whether similar findings would be observed in laparoscopic appendectomy remains uncertain and warrants evaluation in future studies. Additional limitations include the non-randomized allocation of patients, the absence of blinding among surgeons and outcome assessors, and the lack of stratification by surgeon despite standardized technique. Furthermore, the study did not include a "no lavage" (suction-only) arm, which prevents determining whether either lavage method offers advantages over suction alone, as suggested by high-level guidelines.

Concerns about the cytotoxic potential of antiseptic solutions have historically limited their intraperitoneal use [25, 26]. Full- or half-strength Dakin's solutions (0.5% and 0.25% sodium hypochlorite) possess antimicrobial activity but are associated with fibroblast toxicity and delayed wound healing [27]. In the 1990 s, lower-concentration hypochlorite solutions (approximately 0.025%) were shown to retain bactericidal efficacy with minimal cytotoxicity [17]. More recently, comparative in vitro studies demonstrated that sodium hypochlorite has one of the lowest cytotoxic profiles among commonly used antiseptics, supporting its evaluation in new therapeutic applications [18].

Negative pressure wound therapy with intermittent instillation of antiseptic or antibiotic solutions has shown encouraging outcomes in soft-tissue defects and complex wounds [28], and intraperitoneal instillation of saline has been associated with improved outcomes in temporary abdominal closure for abdominal sepsis [28–30]. These findings highlight an ongoing interest in balanced strategies that combine source control with agents possessing antimicrobial activity but limited cytotoxicity.

The SISHS evaluated in this study is a modified, low-concentration sodium hypochlorite formulation (0.057%) that has been characterized as isotonic and non-cytotoxic in preclinical assessments. Its antimicrobial activity has been demonstrated across a range of bacterial loads, including high-level contamination [19, 20]. Although the present study cannot establish causality due to its design, the observed associations between SISHS lavage and improved postoperative parameters—along with lower complication rates and reduced reoperation frequency—suggest that this solution may warrant further investigation as an adjunct in the management of complicated appendicitis.

Guideline recommendations, including the Jerusalem guidelines [31], have historically concluded that peritoneal irrigation has no clear advantage over suction alone in complicated appendicitis; however, these statements are based primarily on data derived from saline irrigation. Given the distinct antimicrobial and physicochemical properties of SISHS, further controlled studies are needed to determine whether its effects differ meaningfully from those of saline-based lavage.

Finally, the favorable cytotoxicity profile reported in recent wound-healing literature [18–20], including improved bioburden control compared with saline-based treatment, supports continued evaluation of this isotonic hypochlorite formulation in settings where microbial load plays a significant role in postoperative morbidity.

Conclusions

Complicated appendicitis continues to present a high rate of postoperative complications, and current evidence remains insufficient to establish a definitive consensus regarding the optimal intraperitoneal lavage strategy. In this study, the use of stabilized isotonic sodium hypochlorite solution (SISHS) was associated with shorter hospital stays, fewer postoperative complications, and lower total direct treatment costs compared with saline lavage in open appendectomy for complicated appendicitis.

These findings should be interpreted within the limitations of the non-randomized and unblinded study design. Further well-designed, controlled trials—including comparisons with suction alone and evaluation in laparoscopic procedures—are necessary to determine the true clinical effectiveness and appropriate role of different irrigation solutions and their potential combinations in the management of complicated appendicitis.

Abbreviations

BMI	Body Mass Index
INC	Incorporation
iOS	iPhone Operating System
macOS	Macintosh Operating System
mg	Milligrams
mL	Milliliters
mm	Millimeters
MXN	Mexican Peso
NPWT	negative pressure wound therapy
n	number
NaOCl	sodium hypochlorite
p	probability value
SS	Saline Solution
SISHS	Stabilized Isotonic Sodium Hypochlorite Solution
SPSS	Statistical Package for the Social Sciences
USA	United States of America

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Author contributions MAML: Conceptualization, Project administration, Data curation, Resources, Methodology, Formal analysis, Writing - Original Draft, Writing - Review & Editing.MCAJ: Conceptualization, Project administration, Data curation, Formal analysis, Writing - Original Draft.RGL: Project administration, Writing - Review & Editing.RDMC: Conceptualization, Project administration, Supervision, Resources.STL: Conceptualization, Project administration, Supervision, Resources.AQG: Conceptualization, Data curation, Formal Analysis, Writing - Original Draft.AMJM: Supervision, Data Curation, Writing - Review & Editing. HPA: Project administration, Data curation, Resources, Writing - Review & Editing, Supervision.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Ethical approval and consent to participate This project was evaluated and approved by the corresponding ethics committee and the corresponding research committee. Both committes assigned the approval number R-2024-1912-028.

Consent for publication Written informed consent was obtained from all participants or their legal representatives for publication data.

Competing interests The authors declare no competing interests.

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