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Comparison of Gentamicin Saline Solution and Normal Saline in Reducing Surgical Site Infections in Open Appendectomy: A Randomized Controlled Trial

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ABSTRACT

Background and Aims: Surgical site infections (SSIs) are a significant source of morbidity and healthcare costs following open appendectomy, particularly in resource-limited settings. While wound irrigation with antimicrobial agents has shown potential in reducing SSI rates, evidence comparing gentamicin-saline solution with normal saline is limited. This study aimed to determine whether gentamicin-saline irrigation reduces SSI rates compared to normal saline alone and to identify patient-related risk factors associated with SSI development.

Methods: This single-centre, single-blinded, randomized controlled trial included 190 patients undergoing uncomplicated emergency open appendectomy between June 2022 and June 2023. Patients were randomly assigned to two groups: one receiving 160 mg gentamicin in 400 mL normal saline for wound irrigation, and the other receiving normal saline alone. The primary outcome was the incidence of SSI within 30 days. Secondary outcomes included length of hospital stay and association of SSI with risk factors such as BMI, smoking, and alcohol use. Statistical analysis was performed using SPSS v.26. Group differences were assessed using independent *t*-tests and Fisher's exact or χ^2 tests as appropriate. A p value < 0.05 was considered statistically significant.

Results: Among 190 patients (95 per group), the overall SSI rate was 15.3%, all of which were superficial. The gentamicin group had a lower SSI rate (12.6%) compared to the saline group (17.9%), but the difference was not statistically significant ($p = 0.313$, RR 0.66; 95% CI, 0.298–1.478). Smoking was significantly associated with SSI occurrence ($p = 0.039$), while BMI showed a significant association only in the gentamicin group ($p = 0.008$). No association was observed with alcohol use.

Conclusion: SSIs contribute substantially to patient complications and healthcare expenses, particularly in lower-resource surgical settings. The reduction in SSI incidence using gentamicin-saline was not statistically significant when compared with normal saline as compared to gentamicin-saline irrigation did not significantly reduce SSIs compared to saline alone in uncomplicated open appendectomy. Focus should be placed on modifiable patient-related risk factors, particularly smoking, to reduce SSI incidence in clinical practice.

1 | Introduction

Acute appendicitis, with an incidence of 96.5 to 100 occurrences per 100,000 annually, is the most prevalent abdominal surgical emergency worldwide [1]. Antibiotics may be a safe alternative to surgery for treating uncomplicated acute appendicitis, but surgery remains the gold standard [2]. Alvarado score and other scoring systems help stratify patients' risk [3]. While appendectomy remains the standard treatment, with laparoscopic approach considered the gold standard. Laparoscopic appendectomy offers benefits such as reduced pain, faster recovery, and shorter hospital stays compared to open surgery [4]. Though laparoscopic appendectomy has become the standard of care for acute appendicitis in numerous centers and hospitals around the world, however open appendectomy still has its place in the resource-limited countries where access to minimally invasive surgery in the emergency setting may not be feasible [5]. Surgical site infections (SSIs) are defined as infections occurring in an incisional site within 30 days after a surgical procedure in which the incision was made or within 90 days if a prosthesis is implanted. SSIs are broadly classified into superficial, deep incisional, and organ-space infections, as per international guidelines such as those from the CDC [6]. SSI remains a significant clinical obstacle as they are associated with substantial mortality and morbidity and imposes severe demands on healthcare resources.

These infections often prolong hospitalization and elevate medical costs due to the need for additional interventions. The main additional costs are related to reoperation, extra nursing care, interventions, and treatment costs. It also costs indirectly due to loss of productivity; patient dissatisfaction and reduced quality of life have been studied less extensively [7]. Therefore, continuing cautiousness is required to minimize the incidence of such infections. This encompasses a systematic approach with attention to multiple risk factors related to the patient, the procedure, and the hospital environment [8]. Data from the United States Centers for Disease Control National healthcare safety Network (CDC NHSN) show that SSIs are the most common and costly of all hospital acquired infections, which accounts for 20% of all hospital-acquired infections [6, 9]. Similarly, European data suggest that the incidence of SSIs may be as high as 20% depending on the procedure, the surveillance criteria used, and the quality of data collection. The incidence of SSI varies widely according to the procedures, hospitals, surgeons, and patients [10]. Several patient-related and procedure-related risk factors of SSI have been shown in multivariate analyses. Procedure-related factors include poor surgical technique, duration of surgery, quality of skin preparation, and inadequate sterilization of surgical instruments preoperatively [8, 11]. Recent studies have identified age and low serum albumin concentrations as the most important patient-related factors [6]. Intraoperative wound irrigation before skin closure represents a pragmatic and economical approach to reduce postoperative SSI after abdominal surgery. The Centers for Disease Control and Prevention have not issued any recommendations regarding the use of wound irrigation with or without antibiotic added solution. Many attempts have been made to reduce the incidence of SSI after appendectomy, one of which was wound irrigation with antimicrobial solutions [5, 12].

Aminoglycoside antibiotics are particularly potent against Enterobacteriaceae family, which includes *Escherichia coli* and Enterococcus. These are the most common organisms causing SSI after appendectomy [13–15]. Relative to other aminoglycosides covering the same group of organisms, gentamicin is readily available at a lower cost. Furthermore, gentamicin has documented benefits in reducing the volume of drainage and wound contamination in other wounds such as axillary dissection and episiotomy wounds [16, 17].

Previous research in diverse surgical fields, including abdominal, orthopedic, and neurosurgical procedures, has evaluated the efficacy of antimicrobial irrigation for SSI prevention [17–19]. Studies on Gentamicin, an aminoglycoside antibiotic effective against common pathogens like *Escherichia coli* and Enterococcus, indicate its potential in reducing SSI rates, especially in high-risk surgeries. However, the efficacy of Gentamicin in open appendectomy remains underexplored, warranting further investigation in this study to determine its applicability in reducing SSI risk in uncomplicated cases. Antimicrobial irrigation has shown promise in reducing SSIs across various surgical specialties. In neurosurgery, antibiotic irrigation, particularly with vancomycin, gentamicin, or streptomycin, has demonstrated efficacy in decreasing SSI rates [20]. A study on emergency neurosurgery found that gentamicin irrigation significantly reduced 28-day SSI rates by 86.7% compared to saline irrigation alone. In orthopedic surgery, while the efficacy of antibiotic irrigation remains inconclusive, gentamicin is considered a cost-effective option for intraoperative lavage due to its microbiologic and safety profile [19]. Only a few studies have been done, and they did not reach a clear consensus on whether antimicrobial irrigation is beneficial or not in preventing SSI in open appendectomy wounds [5, 12]. Hence, the present study was conducted with the prime objective of comparing the efficacy of Gentamicin saline irrigation with only saline irrigation for the prevention of SSI in patients undergoing uncomplicated emergency open appendectomy. Uncomplicated appendicitis represents a relatively homogeneous patient group, minimizing confounding factors such as perforation, abscess formation, or peritonitis, which are associated with significantly higher risks of SSI. By focusing on these cases, we aimed to assess the direct impact of irrigation solutions on infection rates without interference from disease complexity. This highlights the importance of the findings in resource-limited settings where uncomplicated appendectomies are common and low-cost interventions are preferred. The primary objective of this study is to determine the incidence of surgical site infections (SSI) following wound irrigation with gentamicin saline solution compared to normal saline solution in cases of Open Appendectomy. Specifically, the study aims to assess the rates of SSI, while also identifying common risk factors such as BMI, smoking, and alcohol use that may influence infection rates.

The research question explores which irrigation solution, gentamicin saline or normal saline, is more effective in reducing SSI in open appendectomy wounds. The null hypothesis (H0) posits no significant difference between the two solutions, while the alternative hypothesis (H1) suggests that gentamicin saline solutions are more effective in reducing SSI.

2 | Methodology

2.1 | Study Design and Settings

This study was a single-centered, single-blinded, comparative (experimental) prospective quantitative analysis from the Department of General Surgery of our Hospital in the period from June 2022 to June 2023 with a total duration of 12 months. As a tertiary hospital, where patients from across the country come for health checkups and interventions, this center also provides generalized data. The study protocol received approval from the Institutional Review Board, our institution, and has been registered on the Research Registry portal. This study has been reported in accordance with the Consolidated Standards of Reporting Trials (CONSORT) Guidelines [21] (Figure 1).

2.2 | Eligibility Criteria

The inclusion criteria for the study were all patients undergoing open appendectomy who provided written informed consent. Exclusion criteria included patients with appendicular mass, appendicular abscess, or appendicitis with generalized peritonitis, as well as those with acute abdomen due to other causes or a normal appendix as revealed intraoperatively. This study focused on patients with uncomplicated appendicitis to minimize the variability in SSI risk factors, as complicated cases of appendicitis (e.g., cases with abscess, gangrene, or perforation) are associated with inherently higher SSI rates. Including only uncomplicated cases enabled a clearer assessment of the efficacy of gentamicin-saline irrigation versus normal saline irrigation on SSI prevention in a relatively homogeneous patient group. Patients with uncomplicated appendicitis were selected to control for variability in infection risk factors, such as the presence of appendicular abscess or perforation, which could confound the efficacy of the irrigation solutions. Excluding complex cases allowed for a more focused analysis of the interventions. Additionally, patients on long-term steroid therapy or immunosuppressive treatment, and those unwilling to participate in the trial, were excluded from the study.

Inclusion criteria

- All Patients undergoing open appendectomy.
- Written informed consent.

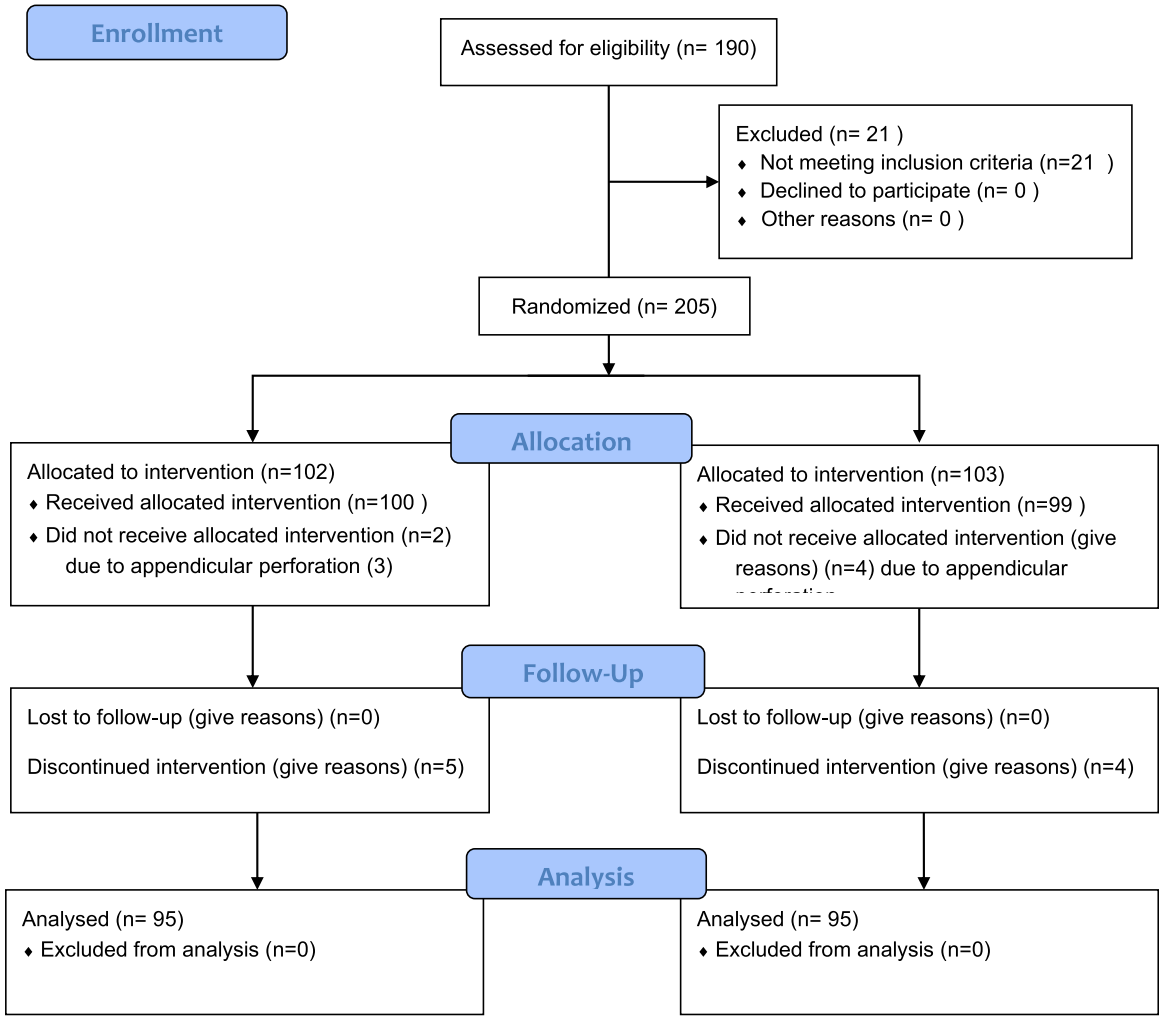

FIGURE 1 | Consort flow chart.

Exclusion criteria

- Patient with appendicular mass, appendicular abscess, appendicitis with generalized peritonitis.
- Acute abdomen due to other causes as revealed intraoperatively.
- Patients with a normal appendix as revealed intraoperatively.
- Patients taking long courses of steroid therapy or immunosuppressive treatment.
- Patients unwilling to participate in the study.

2.3 | Study Variables

In the study, the preoperative data collected includes the patient's age, gender, body mass index (BMI), history of smoking and alcohol consumption, preoperative blood investigations, and any comorbid conditions such as hypertension (HTN), chronic obstructive pulmonary disease (COPD), diabetes mellitus (DM), or other relevant health issues. During the operative phase, data on the type of wound and intraoperative findings are recorded. Postoperatively, the study tracks the occurrence of SSIs, categorizes the types of SSIs, and monitors the length of hospital stay.

2.4 | Randomization

Randomization was conducted at the time of surgery, immediately before the closure of the wound. Patients were randomly assigned to one of two equal groups, ensuring unbiased allocation and comparability across the study arms. Participants were randomly allocated into groups using a computer-generated sequence accessed from an online randomization tool (https://www.randomizer.org/#randomize). A computer-generated randomization sequence was used to assign patients to each irrigation group. To ensure allocation concealment, the randomization sequence was managed by a third party, who prepared sealed, opaque envelopes. These envelopes contained group assignments and were opened by the surgical team immediately before the wound closure stage. This approach ensured unbiased allocation while maintaining the integrity of the randomization process. The participants were divided into one group receiving Gentamycin-Saline irrigation group: 160 mg of gentamicin in 400 mL of normal saline 0.9% used for irrigation of wound on closure, and another group receiving Normal saline irrigation group: 0.9% normal saline used for irrigation of wound on closure.

All the patients undergoing uncomplicated emergency open appendectomy by General Surgery, meeting the inclusive criteria, were considered for the study. The diagnosis of acute appendicitis was pathologically confirmed for all patients included in the study through histopathological examination post-surgery. This confirmation was performed to validate the clinical diagnosis and ensure uniformity in the study population. After excluding three participants with appendicular perforation, 100 patients were treated with gentamycin saline irrigation, and after excluding four participants with appendicular perforation in the saline-only group, 99 were treated with the saline-only group. Ninety-five patients followed up for 30 days and were included in the study. Self-designed semi-structured Proforma was used for data collection procedure along with written informed consent was obtained from all enrolled patients. The study utilizes a nonrandom sampling approach. It employs a parallel group assignment model for the intervention, and a single-blinded procedure was applied where the patient was unaware whether they were assigned to the Group receiving Gentamycin-Saline irrigation or Normal Saline irrigation only during wound closure. To ensure the rigor of the study design, the single-blind methodology was employed. While patients were unaware of their assigned group (gentamicin-saline irrigation or normal saline irrigation), blinding was also extended to the outcome assessors. The assessors evaluating the surgical site for signs of infection were kept unaware of the irrigation solution used, minimizing potential bias in outcome reporting. Additionally, outcome assessors were blinded to the irrigation solution used, which helped minimize bias in SSI outcome evaluation. These measures (blinding of assessors, surgeon training, and rigorous allocation concealment) were designed to enhance the reliability of the findings and minimize bias arising from procedural inconsistencies or observational errors.

2.5 | Procedure

The procedure for this study involved several key steps. Initially, a clinical examination was conducted to diagnose acute appendicitis, followed by baseline investigations, which included a complete and differential blood count, urine routine examination, viral serology for Hepatitis B, C, and HIV, as well as renal function tests and PT/INR. Additionally, an ultrasound of the abdomen and pelvis was performed. Patients showing signs of perforation peritonitis were excluded from the study. Informed and written consent was obtained from all participants. Preoperative antibiotics were administered, consisting of 1 g of Ceftriaxone and 500 mg of Metronidazole for adults, with dosages adjusted according to weight for children. Aseptic precautions were strictly followed in the operating theatre during the entire procedure, including painting and draping. The type of incision, either Gridiron or Lanz, was decided by the duty doctor. The abdomen was opened in layers, and intraoperative findings were carefully noted. The mesoappendix and appendix were identified, ligated, and cut, with hemostasis secured afterward.

The peritoneum was closed using Polyglactin 2-0 continuous sutures. All surgeons involved in the study received standardized training on the irrigation protocol, including the volume of saline solution, method of application, and timing during surgery. This training aimed to maintain consistency across all procedures and minimize variability in SSI outcomes. For wound irrigation, either gentamicin-saline solution (160 mg of gentamicin in 400 mL of 0.9% normal saline) or only normal saline was used during closure, with dressings applied afterwards. Postoperatively, patients were given intravenous antibiotics, analgesics, proton pump inhibitors, and maintenance IV fluids for 24 h.

2.6 | Post Operative

After this period, intravenous medications were switched to oral forms. A liquid oral diet was permitted after 6 h of post-surgery, progressing as tolerated in subsequent days. During the hospital stay, the wound was examined on the first postoperative day for signs of SSI using CDC criteria. If SSI or fluid collection were detected, the wound was opened, and a sterile swab was collected for culture and sensitivity testing. If no SSI was present, alternate-day dressing changes and examinations were conducted. The postoperative day on which SSI developed, as well as the type of SSI and the length of hospital stay, were recorded.

2.7 | Follow Up

Postoperative follow-up adhered to standardized guidelines. Wounds were assessed using CDC criteria for SSIs on the first postoperative day and every alternate day during the hospital stay. Follow-up evaluations continued on an outpatient basis at 1- and 4-weeks post-discharge. A uniform protocol for SSI documentation, including swab collection for microbiological testing when infections were suspected, ensured consistent outcome reporting.

2.8 | Outcome Parameters

The primary outcome of the study was the occurrence of SSI within 30 days following surgery, along with the risk factors associated with SSI. Secondary outcomes included the classification of the types of SSI, duration of hospital stay, and readmission after surgery.

2.9 | Sample Size

The sample size for this trial was determined with respect to the study's primary outcome, which was the occurrence of incisional SSIs within 4 weeks following surgery. According to a systematic review, the combined weighted SSI rate after appendectomy in countries with low and middle Human Development Index (HDI) stands at 17.9% (95% CI: 10.4%–25.3%). It was hypothesized that SSI incidence would be 5% following wound irrigation with a gentamicin-saline solution, compared to 18% when no irrigation was performed before wound closure. With the sample size calculation formula for two proportion sample size was calculated as shown below [22].

Sample size calculation

$$n = \{2(z\alpha + z\beta)^2 pq\}/(p1 - p2)^2 = \{2(1.96 + 0.84)\,2 * 11.5 * 88.5\}/(5 - 18)\,2 = 95 \text{ per group}$$

(total sample size = 190)

Where,

n = sample size needed in each group

$z\alpha = 1.96$ (From Z table) at type 1 error with 5% confidence interval

$Z\beta = Z0.20 = 0.842$ (From Z table) at 80% of power

$p = (p1 + p2/2) = 11.5$

$q = 100 - p = 100\text{-}\ 11.5 = 88.5$

$p1$ = percent of SSI in group I = 5

$p2$ = percent of SSI in group II = 18

$p1 - p2$ = Difference in proportion of events in two groups (13%)

Therefore, the sample size is 95 in each group.

2.10 | Statistical Analysis

Data entry and preliminary visualizations (pie charts and bar diagrams) were conducted using Microsoft Excel 2016, while statistical analyses were performed using IBM SPSS Statistics, Version 26 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for demographic and clinical variables. Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables were summarized as frequencies and percentages. Group comparisons for continuous variables (e.g., age, BMI) were assessed using the independent samples t-test. For categorical variables (e.g., SSI incidence, smoking status), We employed χ^2 or Fisher's exact tests depending on the distribution of categorical variables. The primary analysis comparing the proportion of SSIs between the two intervention groups was pre-specified. Relative risk (RR) and 95% confidence intervals (CI) were calculated to assess the strength and precision of association. All statistical tests were two-sided, and a significance threshold of $p < 0.05$ was applied. p values were reported following standard conventions: values < 0.001 as $p < 0.001$, between 0.001 and 0.01 to the nearest thousandth, and ≥ 0.01 to the nearest hundredth. p values > 0.99 were reported as $p > 0.99$. All statistical methods used in this study adhered to the SAMPL (Statistical Analyses and Methods in the Published Literature) guidelines. No interim analyses were performed. Subgroup analyses, including those based on BMI and smoking status, were exploratory and not pre-specified. Statistical abbreviations used include SD (standard deviation), CI (confidence interval), RR (relative risk), and p (p value for hypothesis testing). In line with current statistical reporting guidelines, p values were interpreted alongside effect sizes and confidence intervals and were reported using standardized formatting conventions.

2.11 | Statistical Terms, Abbreviations, and Symbols

p value (p): The probability of observing the data, or something more extreme, under the null hypothesis. A p value less than 0.05 was considered statistically significant. All tests were two-sided unless otherwise stated.

- SD: standard deviation, representing the dispersion of data around the mean.
- CI: confidence interval, representing the range within which the true population parameter is expected to lie with 95% confidence.
- RR: relative risk, used to compare the probability of an event occurring between two groups.
- *t*-test: a parametric test used to compare the means of two independent groups.
- χ^2: a non-parametric test used to determine if there is a significant association between categorical variables.
- Fisher's exact test: a statistical test used to determine associations between categorical variables when sample sizes are small or expected frequencies are low.
- Two-sided test: a statistical test that evaluates the possibility of an effect in both directions (greater or lesser).

3 | Results

3.1 | Characteristics of the Entire Participants

The initial screening of 226 patients were done with the diagnosis of acute appendicitis, whereas 21 of them were excluded since they did not meet inclusion criteria, along with six had appendicular abscess, four had appendicular lump, and 11 had appendicular perforation, and they were excluded. A total of 205 participants were recruited and were finally analyzed. The process of patient's screening, randomization, and follow-up of study participants has been shown in Figures 1 and 2. A total of 190 patients were randomly assigned to a study group. Twenty-one patients were excluded from the per-protocol analysis; six had appendicular abscess, four had appendicular lump, and 11 had appendicular perforation. Two hundred five patients qualified for the intention-to-treat analysis, 102 were assigned with Gentamycin-Saline irrigation, and 103 were assigned with Saline irrigation. Intraoperatively, two patients with gangrenous appendix in the Gentamycin-Saline irrigation group were excluded from the analysis. Similarly, four patients in the Saline irrigation group were excluded: three with perforated appendix and one with gangrenous appendix. Out of 100 patients who were treated with Gentamycin-Saline irrigation, 95 completed follow-up, and out of 99 patients who were treated with Saline irrigation, 95 completed follow-up for 30 days.

Therefore, 190 patients (95 in the Gentamycin-Saline irrigation group and 95 in the Saline irrigation group) were included in the per-protocol analyses (Figure 2). The patients in the two study groups were similar with respect to demographic characteristics, coexisting illnesses, risk factors for infection, duration and types of surgery, hematological and biochemical parameters. Despite the statistical significance of the Alvarado score in both study groups, it lacked any clinical relevance (Table 1).

3.2 | Age Distribution

The mean age of the study population was 28.7 ± 12.2 years (total number of patients = 190). Ranging from 14 to 70 years of age (Figure 3). Most of the population was young adults.

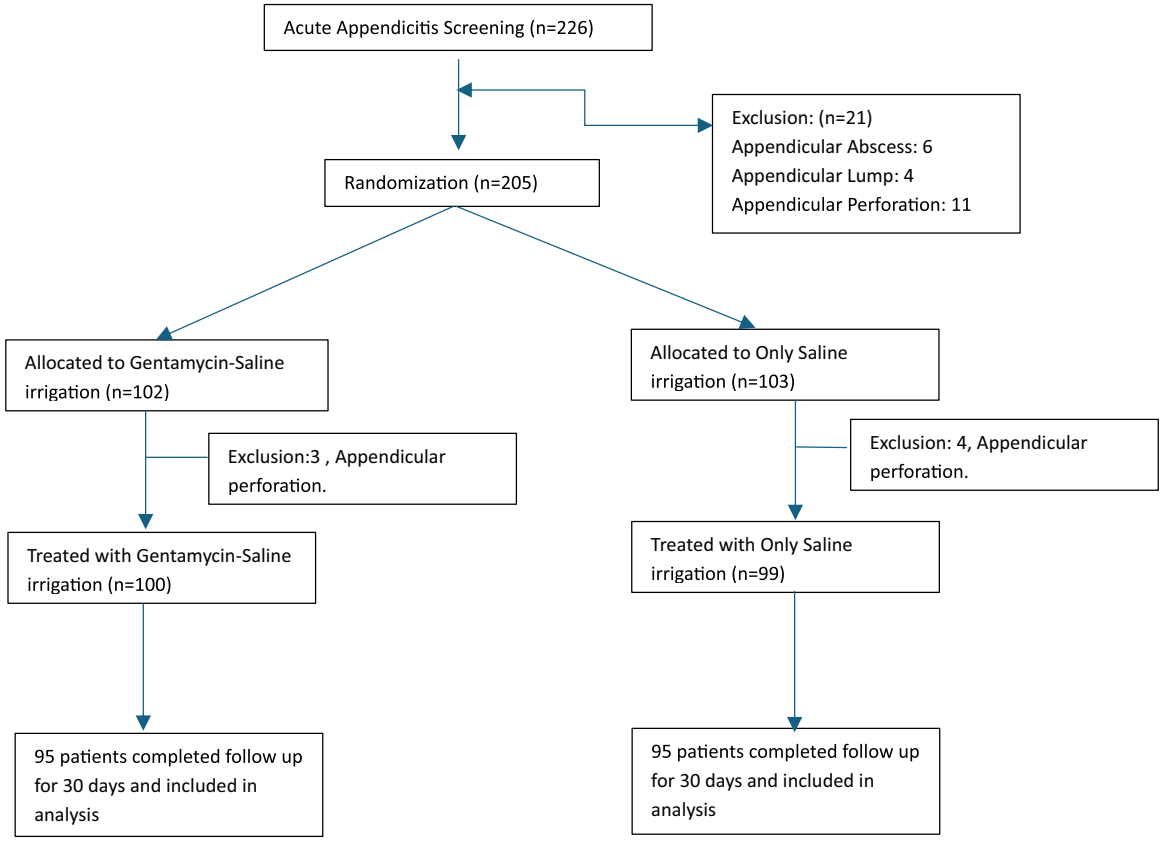

FIGURE 2 | Screening, randomization, and follow-up of study participants.

TABLE 1 | Comparison of baseline characteristics between two groups.

	Gentamycin-saline irrigation ($n = 95$) mean ± SD or number (percentage)	Saline irrigation ($n = 95$) mean ± SD or number (percentage)	*p* value
Age (year)	28.4 ± 11.9	29 ± 12.5	0.766
Sex (Male)	51 (53.7)	60 (63.2)	0.185
Sex (Female)	44 (46.3)	35 (36.8)	
BMI	23 ± 4	22.2 ± 3.9	0.181
Smokers	9 (9.5)	17 (17.9)	0.091
Alcohol intake	11 (11.6)	11 (11.6)	1
Total count	12593 ± 4564.7	13225 ± 3768	0.277
Neutrophil (%)	76.7 ± 10.9	78.1 ± 9.3	0.338
Urea (mmol/L)	3.6 ± 1.1	3.9 ± 1.3	0.228
Creatinine (mmol/L)	70.1 ± 73.3	63.3 ± 15.5	0.376
RBS (mmol/L)	5.6 ± 1.2	5.7 ± 1.3	0.834
Sodium (meq/L)	137 ± 2.2	136.6 ± 2.4	0.242
Potassium (meq/L)	3.8 ± 0.4	3.9 ± 0.3	0.614
Alvorado's score	7.2 ± 1	7.5 ± 1.1	0.045*
Duration of surgery (min)	56.1 ± 6.2	56.9 ± 5.9	0.371
Hospital stay (days)	3.2 ± 0.9	3.3 ± 1.1	0.668

*Statistically significant at $p < 0.05$; independent *t*-test.

3.3 | Gender Distribution

The study population included predominantly males, encompassing 58.4% of the total population, and the remaining 41.6% being females (Figure 4).

3.4 | Presenting Clinical Features

The most encountered presenting clinical features in all the patients were RIF tenderness and rebound tenderness. Fever was the least common clinical feature observed in the study population as depicted in Figure 5.

3.5 | Comorbidities

The incidence of comorbidities among the study population was quite minimal, with hypertension being the most common, followed by diabetes mellitus, Hepatitis B, Hypothyroidism, and triple vessel disease (Table 2). A total of seven patients (3.7%) had diabetes mellitus, and nine patients (4.7%) had hypertension in the study population. Among these, four out of nine hypertensive patients developed SSI. Although the incidence of comorbidities was minimal, hypertension was found to be associated with higher SSI rates, likely due to its impact on tissue perfusion and delayed wound healing.

3.6 | Primary and Secondary Outcomes

Twenty-nine patients (15.3%) who underwent uncomplicated emergency open appendectomy developed superficial incisional SSI. None of the patients had deep or organ space SSI (Table 3). The average length of the hospital stay was 3 days. None of the patients required readmission.

3.7 | Rates of Surgical Site Infection

Although the rate of surgical-site infection was lower in the gentamicin-saline irrigation group (12.6%) compared to the saline-only group (17.9%), Fisher's exact test showed no statistically significant difference ($p = 0.313$). The relative risk of infection was 0.66 (95% CI, 0.298–1.478). There was no significant difference between the two study groups in the incidence of surgical site infection (relative risk 0.66; 95% CI, 0.298–1.478) (Table 4 and Figure 6).

3.8 | Overall Risk Factors Assessment

The association of SSI with different factors was analyzed. Body mass index, smoking status, and drinking status were the main factors assessed. Among these, smoking was found to be significantly associated with surgical site infection (Tables 5–7).

3.9 | Body Mass Index

In the gentamicin-saline group, higher BMI was significantly associated with SSI (χ^2 test, $p = 0.008$). However, this association was not statistically significant in the saline-only group ($p = 0.891$), with higher SSI rates observed among overweight and obese patients. This correlation was not statistically

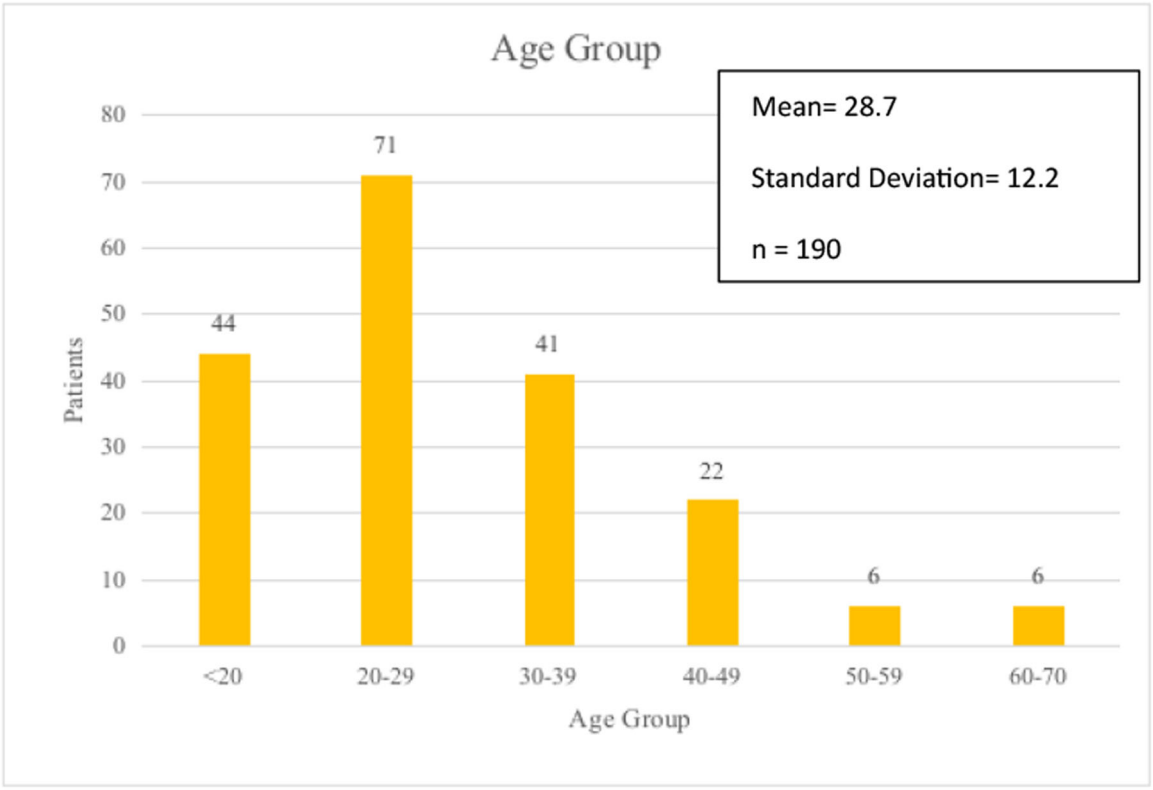

FIGURE 3 | Age distribution of study population.

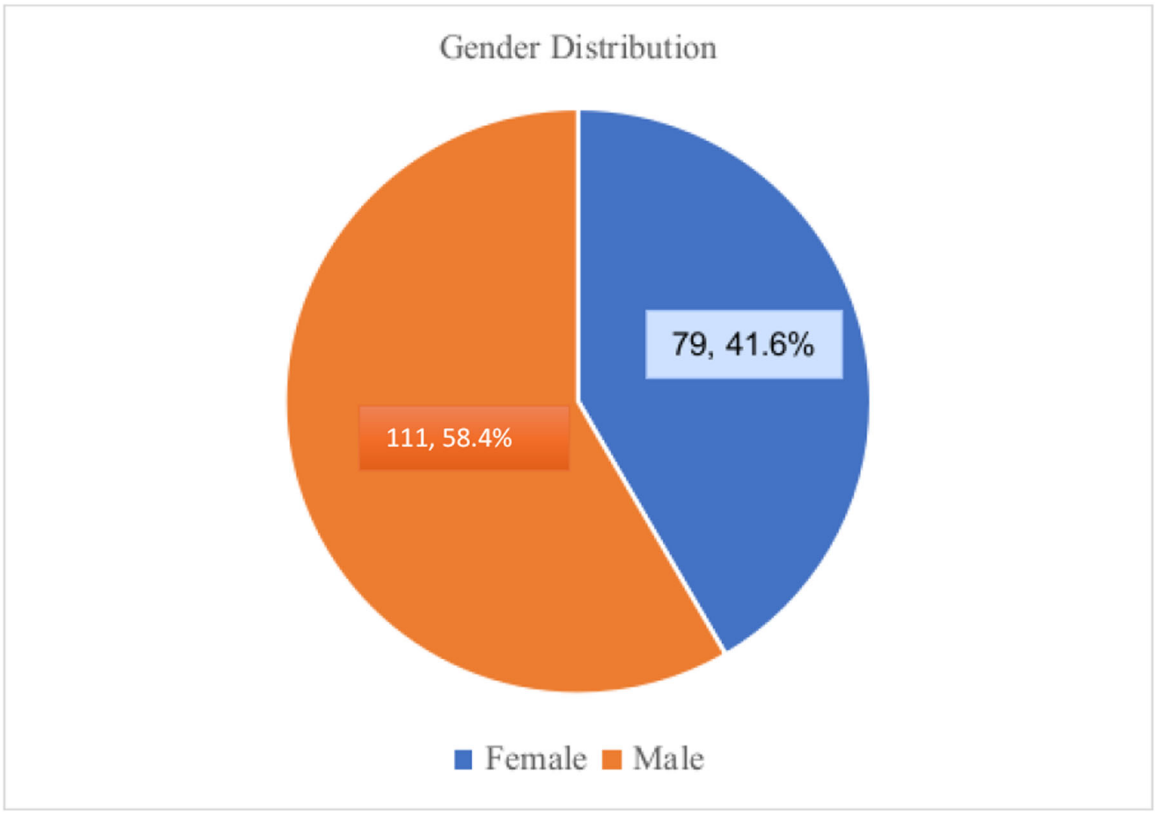

FIGURE 4 | Gender distribution of study population.

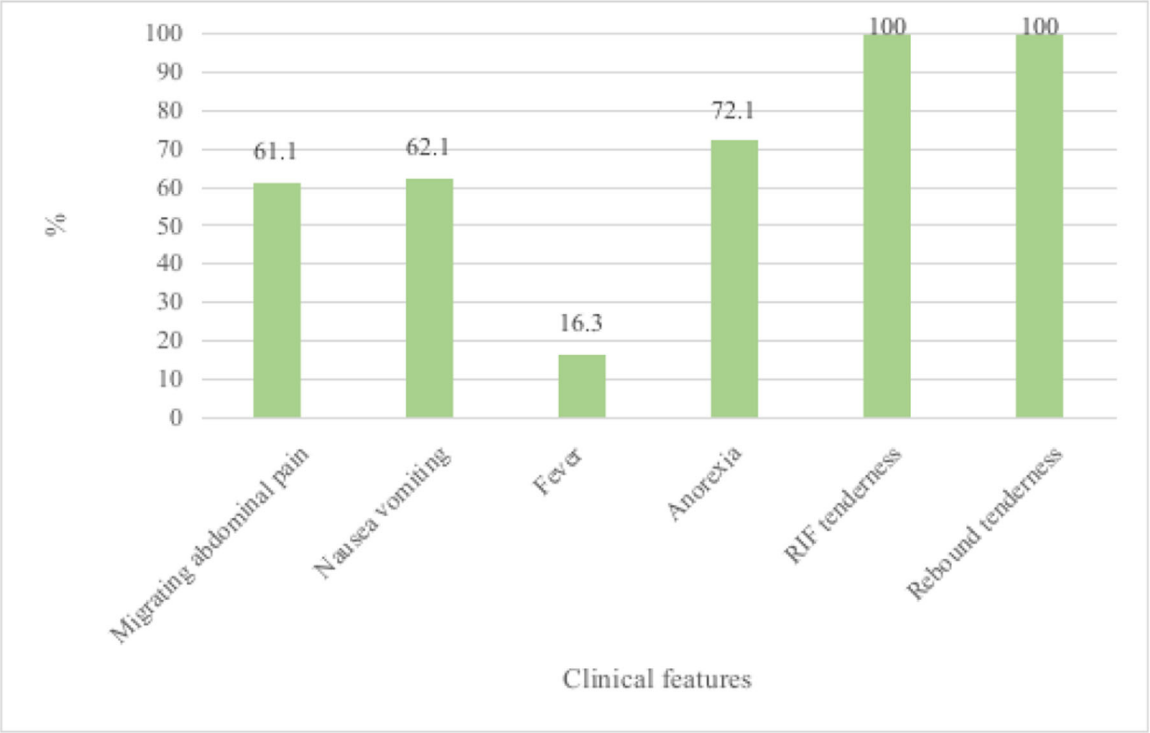

FIGURE 5 | Presenting clinical features of study population.

TABLE 2 | List of comorbidities among the study population.

	Frequency	Percent
Diabetes mellitus	7	3.7
Hypertension	9	4.7
Hepatitis B	1	0.5
Hypothyroidism	1	0.5
Triple vessel disease	1	0.5

TABLE 3 | Proportion of SSI among study group ($n = 190$).

Characteristics	Category	Number	Percentage
SSI	Yes	29	15.3
	No	161	84.7
Total		$n = 190$	100

significant in the normal saline irrigation group ($p = 0.891$). These findings suggest that BMI plays a differential role in SSI outcomes depending on the irrigation solution used (Table 8).

3.10 | Smoking

A statistically significant association was observed between smoking and surgical site infection in the normal saline group (χ^2 test, $p = 0.039$), suggesting smoking as a modifiable risk factor. This association was observed in the patients treated with Normal saline as wound irrigation. In this group, six patients who smoked developed SSI while eleven patients who did not smoke developed SSI (Table 9). These results highlight smoking as a critical modifiable risk factor for SSI prevention.

3.11 | Alcohol

No statistically significant association was observed between alcohol intake and SSI in either group (Fisher's exact test, $p = 0.533$ in the gentamicin-saline group, $p = 0.721$ in the saline-only group) (Table 10). The lack of significance could be due to the small sample size and potential underreporting of alcohol use.

4 | Discussion

Acute appendicitis is the most common cause of acute abdomen, and surgery is the only curative treatment. This study showed a greater magnitude of acute appendicitis in young adults in the age group 21–30 years (37.36%), followed by the 11–20 years age group. Incidence was higher in males (58.4%). Other tertiary centers of our country showed similar incidences in young adults [23, 24]. The peak in development of lymphoid tissue occurs at adolescence which increases the liability of appendix for obstruction, thus high appendicitis incidences in young age groups [25]. Acute appendicitis is diagnosed clinically with supportive investigations. The most common presenting symptoms of acute appendicitis are abdominal pain, nausea, vomiting, and delayed presentation, which are associated with greater morbidity [26]. Our study showed RIF pain with tenderness and rebound tenderness as the most common presenting feature present in all study populations followed by anorexia (72%), nausea/vomiting (62%), migrating pain (61%),

TABLE 4 | Proportion of patients with surgical-site infection.

Surgical site infection	Gentamycin-saline irrigation ($n = 95$)	Saline irrigation ($n = 95$)	Relative risk ((95% CI)[a]	p value[b]
Present	12 (12.6)	17 (17.9)	0.66 (0.298–1.478)	0.313
Absent	83 (87.4)	78 (82.1)		

[a]Relative risks are for gentamycin-saline as compared with only saline irrigation.
[b]p values are based on χ^2 test.

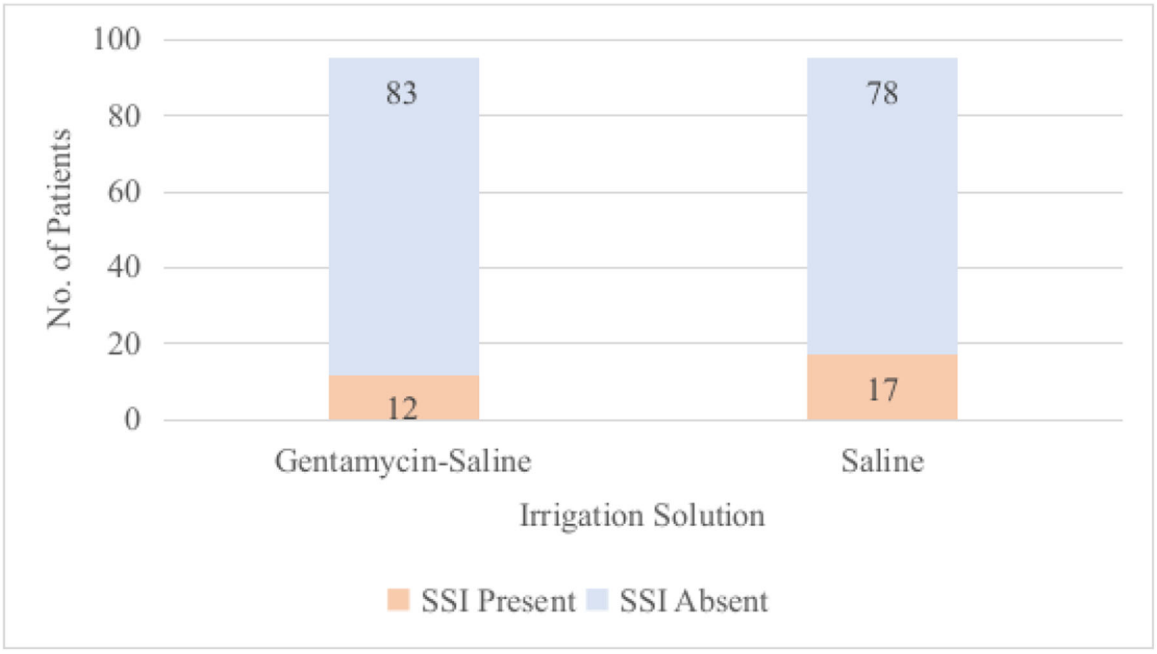

FIGURE 6 | Irrigation solution and SSI.

TABLE 5 | The association of BMI with SSI.

BMI category	SSI ($n = 29$)	No SSI ($n = 161$)	Total	p value
Underweight	2	18	20	0.058
Normal	15	109	124	
Overweight	8	28	36	
Obese	4	6	10	

TABLE 6 | The association of smoking status with SSI.

	SSI ($n = 29$)	No SSI ($n = 161$)	Total	p value
Smoker	8	18	26	0.018*
Nonsmoker	21	143	164	

*Statistically significant at $p < 0.05$; χ^2 test.

and fever (16.3%). The baseline Alvarado score varied significantly between the two study groups, which may impact on the interpretation of SSI outcomes. Chung et al. indicate that a higher Alvarado Score can be associated with increased risk of postoperative complications, including SSI. This variation could potentially influence the study's findings and suggests a need to account for Alvarado Score in SSI risk assessments in future studies [27].

SSI is one of the common complications of appendectomy and is a health care problem despite recent advancements in surgical treatment and antibiotic development. It is usually associated with additional morbidity and ultimately results in higher healthcare costs, so efforts should be made to decrease the incidence of SSI [28]. SSIs are particularly prevalent in colorectal surgery, where the risk of contamination is higher due to the nature of the gastrointestinal tract. SSIs are considered the most frequent postoperative complication following colorectal procedures, with incidence rates reported between 13% and 21.5%. These infections not only cause substantial patient discomfort and delayed wound healing, but are also associated with increased morbidity, prolonged hospitalization,

TABLE 7 | The association of alcohol intake with SSI.

	SSI ($n = 29$)	No SSI ($n = 161$)	Total	p value
Alcoholic	6	16	22	0.096
Non-alcoholic	23	143	166	

*Statistically significant at $p < 0.05$; χ^2 test.

TABLE 8 | Analyses of the association of BMI with surgical site infection in two groups.

Irrigation			SSI	No SSI	Total	p value
Gentamycin saline	BMI category	Underweight	0	8	8	0.008*
		Normal	4	56	60	
		Overweight	5	16	21	
		Obese	3	3	6	
	Total		12	83	95	
Normal saine	BMI category	Underweight	2	10	12	0.891
		Normal	11	53	64	
		Overweight	3	12	15	
		Obese	1	3	4	
	Total		17	78	95	

Note: *Indicates statistically significant difference at the 5% level ($p < 0.05$).

TABLE 9 | Analysis of the association of smoking status with surgical site infection in two groups.

Irrigation		SSI	No SSI	Total	p value
Gentamycin saline	Smoker	2	7	9	0.363
	Nonsmoker	10	76	86	
	Total	12	83	95	
Normal saline	Smoker	6	11	17	0.039*
	Nonsmoker	11	67	78	
	Total	17	78	95	

Note: *Indicates a statistically significant association at the 5% significance level ($p < 0.05$).

TABLE 10 | Analysis of the association of alcohol status with surgical site infection in two groups.

Irrigation		SSI	No SSI	Total	p value
Gentamycin saline	Alcoholic	2	9	11	0.556
	Nonalcoholic	10	74	84	
	Total	12	83	95	
Normal saline	Alcoholic	4	7	11	0.089
	Nonalcoholic	13	71	84	
	Total	17	78	95	

unplanned readmissions, sepsis, and even mortality. Moreover, the economic burden of managing SSIs after colorectal surgery is significant due to extended hospital stays and additional interventions. Recent studies underscore the importance of stringent infection prevention measures in colorectal operations to reduce these complications and improve outcomes [29, 30].

In addition to surgical site infections, intra-abdominal abscess (IAA) formation is another significant postoperative complication in appendectomy. Studies indicate that IAA rates are generally higher after laparoscopic appendectomy compared to open approaches, especially in complicated appendicitis cases. Expectant (nonoperative) management, while increasingly

explored in uncomplicated appendicitis, has also been associated with abscess formation in some cases due to delayed or incomplete resolution of infection. A recent systematic review reported IAA rates of approximately 4.9% following laparoscopic appendectomy, compared to 2.4% after open appendectomy, while expectant management showed an IAA rate of 3.8% [31].

We hypothesized that contamination may occur across multiple tissue layers during surgery, warranting thorough irrigation to reduce microbial burden. Therefore, we recommended saline solutions or antibiotic-saline solutions that may remove all possible contaminants from every layer, lowering the frequency of both deep and superficial incisional SSI. Compared to only saline irrigation, gentamicin irrigation has shown a significant decrease in surgical site infection rates in ventral hernia repairs (16.5% vs. 5.4%, $p < 0.001$) [18]. Comparable outcomes have been documented in neurosurgery, where gentamicin irrigation has reduced SSIs in craniotomy-related interventions [19, 32]. Sameh Hany Emile similarly did randomized control trial in 205 patients undergoing appendectomy showed no significant difference between gentamicin saline irrigation and only saline irrigation in prevention of Surgical site infection, but it showed a higher incidence of SSI with no irrigation [28]. Even after layer-by-layer wound irrigation on closure of open appendectomy wound in this study, it showed no significant difference between two irrigation groups in terms of prevention of surgical site infection. In our study, the rate of surgical-site infections was lower in the gentamycin-saline irrigation group compared to the saline-only group, the difference was not statistically significant with relative risk of 0.66; 95% CI: 0.298–1.478.

Comorbidities were quite minimal in our study population. Most common was hypertension (4.7%), followed by diabetes mellitus, hepatitis B, hypothyroidism, and triple vessel disease. Four out of nine hypertensive patients developed SSI in this study. Higher rates of intraoperative bleeding and poor soft tissue perfusion with aggressive treatment of hypertension during and after surgery, leading to tissue hypoperfusion and ultimately poor healing, which makes it more prone to SSI [33]. Liu et al. showed significantly less postoperative wound healing problems and lower SSI rates. Smoking delays angiogenesis with weakening of inflammatory healing response and damage to oxidative bacterial killing mechanisms, which leads to surgical site infections. Lastly, smoking causes a delay of proliferative healing response and change in collagen metabolism which leads to further wound complications [34]. Smoking was identified as a significant risk factor for SSI, consistent with previous studies linking tobacco use to impaired wound healing and increased infection risk [34, 35]. Lifestyle factors such as smoking, alcohol consumption, and BMI play crucial roles in patient recovery post-appendectomy. Smoking, for instance, can delay angiogenesis, impair the inflammatory response, and hinder oxidative bacterial killing, all of which increase the risk of infection [35]. Preoperative patient optimization, particularly regarding modifiable lifestyle factors, may be an effective strategy in reducing SSI rates. This aligns with findings in other surgical studies where smoking cessation and BMI management were associated with lower postoperative infection risks [36, 37]. Our study also showed a significant increase in surgical site infection rates in smokers ($p = 0.018$).

SSIs are a significant concern in various surgical procedures, with obesity and alcoholism identified as key risk factors. Obesity has been consistently associated with increased SSI rates, particularly in abdominal and spinal surgeries [36, 38]. Most of the patients studied had a normal body mass index, and there was a low frequency of obesity (5.12%). Although statistical significance was seen in this study, the clinical significance between BMI is not appreciated, as most of the population had a normal BMI. Alcoholism has been identified as an independent risk factor for developing SSIs, with patients with AUD having 2.73 times higher odds of SSI [37]. This study did not show any significant association between alcohol intake and surgical site infection in the study population. This might probably be due to social stigma or recall bias and good surgical techniques, preoperative antibiotics, which might have minimized the impact of alcohol on SSI risk. The lack of a significant difference between the gentamicin-saline and saline-only groups may stem from several factors. Variability in wound size and the bacterial load of each case could impact SSI risk, possibly masking the effects of the gentamicin solution. Studies have shown that bacterial load plays a crucial role in the development of SSIs, particularly when baseline bacterial colonization varies across patient wounds [39]. Additionally, minor variations in irrigation technique among surgeons, despite training, might have influenced the outcome. Variation in technique, especially in procedures requiring precise application, has been noted as a potential confounding factor in surgical outcomes [10]. Future studies could control these variables by standardizing wound sizes or categorizing bacterial loads to determine if such factors influence irrigation efficacy. Surgical site infections (SSIs) following appendectomy significantly impact patient outcomes and healthcare costs. Patients with SSIs experience longer hospital stays, with an average increase of 6.5–9.7 days [40]. Complicated appendicitis is associated with a higher incidence of SSIs, increased hospital length of stay, and readmission rates compared to simple appendicitis, and also are associated with confounding factors. By focusing exclusively on uncomplicated appendicitis, the study minimized confounding factors, such as the severity of infection and associated complications, allowing for a clearer evaluation of the intervention's efficacy. In our case, the average hospital stay length was 3 days, and none of the participants were readmitted after the surgery. However, this may be attributed to uncomplicated open appendectomy cases, the majority of which involved young patients with minimal comorbidities. It is important to note that none of the patients included in this study were immunosuppressed, as those receiving long-term steroid or immunosuppressive therapy were excluded. Acute appendicitis in immunosuppressed patients is often difficult to diagnose and is associated with increased morbidity and mortality. This presents a significant clinical challenge, as physicians must carefully weigh the risks and benefits of surgical intervention versus expectant management in this vulnerable population [41]. In addition to traditional risk factors such as smoking and BMI, emerging research has explored the role of biochemical markers in predicting surgical site infections. Recent evidence suggests that decreased levels of Butyrylcholinesterase (BuChE), an enzyme produced in the liver, may serve as a useful biomarker for early identification of patients at higher risk for SSI. BuChE levels are thought to reflect systemic inflammation and metabolic stress, which are often present in patients who go on to develop

postoperative infections. A recent study demonstrated that lower BuChE levels correlated with a higher incidence of SSIs, suggesting its potential as a predictive tool in surgical settings, including abdominal procedures [42].

5 | Practical Implications

The study's findings have practical implications for surgical practice, particularly in resource-limited settings. It demonstrated that irrigation with Gentamicin saline solution was not significantly more effective than normal saline in preventing SSIs in uncomplicated open appendectomy. This suggests that normal saline, a more cost-effective option, can continue to be used for wound irrigation without the added expense of Gentamicin. Additionally, the study identified that risk factors like smoking and obesity play a more significant role in SSI occurrence, indicating that prevention efforts should focus on managing these factors rather than relying on antimicrobial irrigation. This simplifies surgical protocols, reduces unnecessary antibiotic use, and reduces health costs.

6 | Limitations

The limitations of this study include its single-center design, which may limit the generalizability of the findings to other healthcare settings with different patient populations or surgical practices. The study focused only on uncomplicated open appendectomy cases, excluding more complex scenarios such as appendicular abscesses or perforations, which limits the applicability of the results to broader surgical contexts. Although the results may not directly apply to complicated appendicitis cases, they provide valuable insights for resource-limited settings where uncomplicated appendectomies are more prevalent. Expanding the study to include multiple centers with larger, more diverse patient populations would enhance the generalizability of the findings. While the homogeneous patient population enhances the study's internal validity, it also limits external validity. Expanding multi-center trials and including more diverse patient groups could provide a more comprehensive understanding. Additionally, investigating the efficacy of Gentamicin saline irrigation in more complex surgical cases, such as those involving appendicular abscess or perforations, could provide valuable insights. This study would benefit from subgroup analysis by factors such as gender, Alvarado Score, and BMI, as these variables may differentially impact SSI outcomes. For instance, understanding how Alvarado Score influences SSI rates in each irrigation group could provide more nuanced insights into the efficacy of gentamicin-saline irrigation. Future studies should consider these subgroup analyses to clarify potential variations in efficacy across different patient profiles. Although microbiological confirmation of SSIs was performed, we did not perform molecular characterization or antibiotic susceptibility profiling of pathogens to assess the potential emergence of gentamicin resistance. Second, no assessments were conducted to evaluate possible local tissue toxicity due to the use of gentamicin irrigation. Third, the study was conducted at a single center, which may limit the generalizability of the results. Additionally, we only included patients with uncomplicated appendicitis, which may not reflect SSI rates or intervention efficacy in complicated cases. Finally, follow-up was limited to 30 days; long-term wound healing and antibiotic resistance trends could not be assessed.

7 | Conclusion

The study concluded that the Gentamicin saline solution was not significantly more effective than normal saline in reducing SSIs in patients undergoing uncomplicated open appendectomy. Despite a lower overall SSI rate in the gentamicin group, the difference was not statistically significant. This suggests that the routine use of gentamicin for wound irrigation may not provide additional benefits over normal saline in such cases. The study also highlighted the importance of managing patient-related risk factors, such as smoking and body mass index, as these were found to have a more significant association with SSI rates. These findings have important implications for surgical practices, especially in resource-limited settings where cost-effective measures are critical.

Author Contributions

Bibek Shrestha: conceptualization, methodology, data curation, formal analysis, writing – original draft, writing – review and editing, visualization, project administration. **Krishna Kumar Yadav:** conceptualization, data curation, formal analysis, methodology, project administration, writing – original draft, writing – review and editing, supervision. **Niravkumar Valjibhai Buha:** conceptualization, data curation, formal analysis, methodology, project administration, writing – original draft, supervision. **Suman Dahal:** conceptualization and supervision. **Pratibha Yadav:** conceptualization and supervision. **Prashant Yadav:** conceptualization and supervision.

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Ethics Statement

Ethical approval was given from Institutional Review Committee (IRC) on May 24, 2022, with reference number: 491 (6-11) E2 078/079.

Consent

Written informed consent was obtained from the patient for the data collection and publication in Journal. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Transparency Statement

The lead author, Bibek Shrestha, affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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