JHWCR
Journal of Health, Wellness, and Community Research
Volume III, Issue VIII
Open Access, Double Blind Peer Reviewed.
Web: https://jhwcr.com, **ISSN**: 3007-0570
https://doi.org/10.61919/ng7apf29

Article

Frequency of Surgical Site Infection in Patients Undergoing Open Appendectomy in Complicated Appendicitis

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Cite this Article

Received	2025-05-13
Revised	2025-06-17
Accepted	2025-07-01
Published	2025-07-05

No conflicts declared; ethics approved; consent obtained; data available on request; no funding received.

Authors' Contributions
Concept: FA, AUA; Design: FA, AUA; Data Collection: NA, SSR, MD; Analysis: FA, AUA; Drafting: FA, HAB

ABSTRACT

Background: Complicated appendicitis presents a significant clinical burden in surgical practice, particularly in resource-limited settings where open appendectomy remains the standard approach. Surgical site infections (SSI) are a common postoperative complication in such cases, contributing to increased morbidity, hospital stay, and readmissions. Despite the global shift toward minimally invasive techniques, data specific to open procedures in high-risk populations remain limited. **Objective**: To determine the frequency of surgical site infections and identify associated risk factors in patients undergoing open appendectomy for complicated appendicitis. **Methods**: A descriptive cross-sectional study was conducted at Lady Reading Hospital, Peshawar, from December 2024 to June 2025. A total of 137 patients aged 15–65 years with clinically and radiologically confirmed complicated appendicitis underwent open appendectomy. Data on demographic, clinical, and perioperative variables were collected. Patients were followed for 30 days postoperatively to assess SSI development based on CDC criteria. Statistical analysis included Chi-square, t-tests, and calculation of odds ratios with 95% confidence intervals. **Results**: The frequency of SSI was 34.3%, with superficial incisional infections comprising the majority (68.1%). Significant risk factors included male gender (OR 2.25), rural residence (OR 3.23), low socioeconomic status (OR 2.94), BMI >25 kg/m^2 (OR 3.52), and operative time >90 minutes (OR 3.57). SSI was associated with longer hospital stays (8.2 vs 4.6 days, $p<0.001$) and delayed return to normal activity. **Conclusion**: SSI rates following open appendectomy for complicated appendicitis remain substantially elevated in resource-constrained environments. Identification of modifiable risk factors provides opportunities for targeted preventive strategies to improve surgical outcomes.

Keywords: Surgical Site Infection; Complicated Appendicitis; Open Appendectomy; Risk Factors; Postoperative Complications

INTRODUCTION

Acute appendicitis remains one of the most frequent surgical emergencies worldwide, with a lifetime risk estimated between 7% and 8% (1). In the South Asian context, including Pakistan, it predominantly affects younger individuals and adolescents, often presenting with abdominal pain, vomiting, and fever—clinical indicators that, when coupled with diagnostic imaging, guide the decision for operative management (2,3). While uncomplicated appendicitis may be managed conservatively with antibiotics in select cases, complicated appendicitis—characterized by perforation, gangrene, abscess formation, or the presence of an appendicolith with peritoneal contamination—almost universally necessitates immediate surgical intervention, typically via appendectomy (4,5). In resource-limited healthcare settings where laparoscopic infrastructure may be sparse, open appendectomy remains the primary mode of surgical treatment for such cases (6).

However, open appendectomy, particularly in the context of complicated appendicitis, is associated with a markedly increased risk of postoperative complications, most notably surgical site infections (SSI). SSIs are among the most common healthcare-associated infections, leading to substantial morbidity, increased hospital stays, readmissions, and elevated healthcare costs (7). These infections are particularly concerning in cases involving contaminated or dirty wounds, such as those encountered in perforated or gangrenous appendicitis, where fecal contamination and inflammatory debris compromise wound healing (8). A systematic review of global data estimated the average SSI rate following appendectomy to be approximately 7%, although this figure is heavily skewed

toward high-income countries with greater access to minimally invasive techniques and robust perioperative infection control (9). In contrast, studies from low-to-middle-income countries (LMICs), including Pakistan, report significantly higher infection rates, especially for open procedures in complex cases. For example, Akbar et al. documented a 27.5% SSI rate following open appendectomy, underscoring the amplified risk in high-burden, resource-constrained environments (10).

Despite widespread recognition of SSIs as a major postoperative challenge, the majority of existing studies in Pakistan and comparable LMIC settings either aggregate data across both simple and complicated appendicitis or fail to differentiate between laparoscopic and open surgical techniques, limiting the applicability of their findings to high-risk populations. Moreover, there is insufficient granular analysis of modifiable risk factors—such as BMI, operative time, socioeconomic background, and rural residence—that might inform targeted interventions for infection prevention. The few studies that focus on complicated appendicitis often lack standardized criteria for diagnosis or postoperative surveillance for SSIs, thereby introducing heterogeneity and limiting their utility in shaping practice guidelines (11,12).

Given these limitations, this study aims to address a critical knowledge gap by determining the frequency of surgical site infection specifically in patients undergoing open appendectomy for complicated appendicitis in a high-volume tertiary care center in Pakistan. It further seeks to identify and analyze patient- and procedure-related risk factors associated with SSI development using standardized clinical and laboratory definitions. By doing so, this research contributes to the regional evidence base, provides insights into modifiable predictors of poor surgical outcomes, and informs clinical protocols to mitigate postoperative infections in similar healthcare environments. The central research objective is thus to determine the frequency of surgical site infections and evaluate the associated demographic, clinical, and intraoperative risk factors among patients undergoing open appendectomy for complicated appendicitis.

MATERIALS AND METHODS

This descriptive cross-sectional study was conducted to determine the frequency and associated risk factors of surgical site infection (SSI) among patients undergoing open appendectomy for complicated appendicitis. The rationale for selecting this design lies in its suitability for estimating prevalence while evaluating associations between risk factors and health outcomes in a defined population within a specific time frame. The study was carried out in the General Surgery Department of Lady Reading Hospital, a high-volume tertiary care center in Peshawar, Khyber Pakhtunkhwa, Pakistan. The data collection period extended from 20th December 2024 to 20th June 2025.

The study population included male and female patients aged 15 to 65 years who presented with clinically and radiologically confirmed complicated appendicitis and underwent open appendectomy. Complicated appendicitis was operationally defined by the presence of at least two of the following clinical indicators: fever ≥38°C, vomiting or nausea, and abdominal pain with a Visual Analogue Score (VAS) greater than 3, along with supportive laboratory evidence (leukocytosis >15,000 cells/mm^3) and imaging findings (appendicular diameter >1 cm with periappendicular collection or abscess on ultrasound or CT scan). Patients with psychiatric disorders, coagulation abnormalities, hemodynamic instability, pregnancy or lactation, or those requiring conversion to laparoscopic surgery were excluded to ensure homogeneity of the operative and clinical management pathway.

Participants were selected using a consecutive non-probability sampling method based on the order of presentation to the emergency department. Eligible patients who met the inclusion criteria and consented to participate were enrolled after being provided with a detailed explanation of the study's purpose, procedures, and potential risks and benefits. Written informed consent was obtained from all participants or their legal guardians, and confidentiality was assured.

Demographic and clinical data were collected prospectively using a structured, pre-validated proforma administered by the primary researcher at baseline and during follow-up visits. Variables collected included age, sex, residence (urban or rural), socioeconomic status (categorized as low, middle, or high based on income brackets), BMI (calculated as weight in kg divided by height in m^2), duration of hospital stay, operative time, and clinical outcomes such as SSI, readmission, and return to normal activity. Socioeconomic status was self-reported and cross-referenced with occupation and educational attainment when available. BMI was stratified using WHO criteria, with >25 kg/m^2 considered elevated.

All patients underwent standardized open appendectomy via a right lower quadrant muscle-splitting incision under general anesthesia. Operative time was recorded from skin incision to closure. Postoperative wound care adhered to the hospital's infection control protocols. Follow-up assessments for SSI were conducted on postoperative days 3, 7, 14, and 30 by a senior surgical resident under consultant supervision. SSI was diagnosed based on CDC criteria, which included the presence of purulent discharge, localized pain or tenderness, redness, swelling, or spontaneous wound dehiscence. Infections were classified as superficial incisional, deep incisional, or organ/space. To minimize assessment bias, outcome evaluation was performed by clinicians blinded to patient socioeconomic data.

The sample size was calculated using the WHO sample size calculator with an anticipated SSI frequency of 35% based on prior regional data (13), absolute precision of 8%, and a 95% confidence level, yielding a minimum required sample of 137 patients. No imputation was performed for missing data; complete case analysis was applied. Data entry and cleaning were conducted in Microsoft Excel, and statistical analysis was performed using IBM SPSS Statistics version 24. The Shapiro–Wilk test was used to assess data

normality. Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range as appropriate. Categorical variables were summarized as frequencies and percentages. Associations between categorical variables and SSI were assessed using Chi-square or Fisher's exact tests, while t-tests were used for comparisons of continuous variables between SSI and non-SSI groups. Effect modifiers such as age, BMI, operative time, and socioeconomic status were controlled through stratification, followed by post-stratification statistical testing. A p-value <0.05 was considered statistically significant. Although this study did not perform multivariable regression due to the sample size, key variables were stratified to assess potential confounding.

This study received ethical approval from the Institutional Ethical Review Committee of Lady Reading Hospital, Peshawar (Reference No. 510/LRH/MTI). Measures were taken to uphold data integrity and reproducibility through standardized data collection forms, calibration of measurement instruments, double-entry validation of electronic datasets, and adherence to a pre-specified analysis plan. All patient records and data were anonymized and securely stored, ensuring compliance with ethical standards and reproducibility requirements.

RESULTS

Among 137 patients included in the study, surgical site infections (SSI) were present in 47 individuals, representing 34.3% of the total cohort. The mean age overall was 28.4 years (±12.6). However, there was a striking age difference between groups: patients who developed SSIs were notably older, averaging 35.2 years (±14.8), compared to 25.1 years (±9.4) among those without infections. This difference was highly statistically significant ($p < 0.001$), and each additional year of age increased the odds of developing an SSI by 6% (OR 1.06; 95% CI: 1.03–1.10).

Age above 40 years was particularly impactful, with 29.8% of SSI patients being over 40, versus only 6.7% among those without infections ($p < 0.001$). This translates into nearly a sixfold higher risk (OR 5.98; 95% CI: 2.07–17.23) for SSI in the older age group. Male sex was also associated with higher infection risk. Overall, 62.8% of the patients were male. Among those with SSI, 74.5% were male, compared to 56.7% in the non-SSI group, yielding a statistically significant difference ($p = 0.032$) and more than doubling the odds of SSI occurrence (OR 2.25; 95% CI: 1.03–4.93). Socio-demographic variables further emphasized disparities. Rural residence was significantly more common among SSI patients—44.7% versus 20.0% in those without infection ($p = 0.001$). Rural patients were over three times more likely to develop SSIs (OR 3.23; 95% CI: 1.48–7.04). Low income was another potent risk factor, with 74.5% of the SSI group classified as low income, compared to 50.0% in the non-SSI group ($p = 0.004$), corresponding to nearly a threefold increased odds of infection (OR 2.94; 95% CI: 1.30–6.67).

Table 1. Baseline Demographic and Clinical Characteristics by SSI Status (N=137)

Variable	Total (N=137)	SSI Present (n=47, 34.3%)	SSI Absent (n=90, 65.7%)	p-value	Odds Ratio (95% CI)
Age, mean ± SD (years)	28.4 ± 12.6	35.2 ± 14.8	25.1 ± 9.4	<0.001	1.06 (1.03–1.10)
Age > 40 years, n (%)	20 (14.6%)	14 (29.8%)	6 (6.7%)	<0.001	5.98 (2.07–17.23)
Male, n (%)	86 (62.8%)	35 (74.5%)	51 (56.7%)	0.032	2.25 (1.03–4.93)
Rural residence, n (%)	39 (28.5%)	21 (44.7%)	18 (20.0%)	0.001	3.23 (1.48–7.04)
Low income, n (%)	80 (58.4%)	35 (74.5%)	45 (50.0%)	0.004	2.94 (1.30–6.67)
BMI > 25 kg/m², n (%)	63 (46.0%)	31 (66.0%)	32 (35.6%)	<0.001	3.52 (1.66–7.46)
Operative time >90 min, n (%)	57 (41.6%)	29 (61.7%)	28 (31.1%)	<0.001	3.57 (1.70–7.48)

Table 2. Comparison of Postoperative Outcomes by SSI Status

Parameter	SSI Group (n=47)	Non-SSI Group (n=90)	p-value	Mean Difference (95% CI)
Hospital stay, days (mean ± SD)	8.2 ± 3.1	4.6 ± 1.8	<0.001	3.6 (2.6–4.6)
Return to normal activity, days	14.3 ± 4.2	8.7 ± 2.5	<0.001	5.6 (4.2–7.0)
Readmission rate, n (%)	10 (21.3%)	6 (6.7%)	0.012	OR: 3.78 (1.25–11.39)
Time to SSI development, days	5.8 ± 2.4	—	—	—
Purulent drainage, n (%)	39 (83.0%)	—	—	—
Warmth/swelling, n (%)	36 (76.6%)	—	—	—
Delayed wound healing, n (%)	34 (72.3%)	—	—	—
Pain/tenderness, n (%)	32 (68.1%)	—	—	—

Elevated BMI emerged as a clinical concern, with 46.0% of all patients having a BMI >25 kg/m². Among those who developed an SSI, 66.0% fell into this higher BMI category, significantly exceeding the 35.6% prevalence in the non-SSI group ($p < 0.001$). This yielded an odds ratio of 3.52 (95% CI: 1.66–7.46), indicating that higher body mass substantially raises SSI risk. Finally, surgical factors played a crucial role. Prolonged operative time (>90 minutes) was observed in 61.7% of the SSI group but only in 31.1% of those without infection ($p < 0.001$). This factor increased the odds of SSI by 3.57 times (95% CI: 1.70–7.48), underscoring the impact of intraoperative duration on postoperative complications.

Postoperative outcomes were significantly worse for patients who developed SSIs. Hospitalization duration more than doubled in the SSI group, with a mean stay of 8.2 days (±3.1) compared to just 4.6 days (±1.8) in the non-SSI group ($p < 0.001$). The mean difference of

3.6 days (95% CI: 2.6–4.6) reflects a considerable burden on both patients and healthcare systems. Functional recovery was similarly delayed. The mean time to return to normal activities was substantially longer in the SSI cohort, averaging 14.3 days (±4.2), compared to 8.7 days (±2.5) in the non-SSI group ($p < 0.001$). The mean delay of 5.6 days (95% CI: 4.2–7.0) highlights the significant personal and economic impact of SSIs. Readmission rates also reflected the burden of infection. Among SSI patients, 21.3% required readmission, markedly higher than the 6.7% rate observed in those without infections ($p = 0.012$). The odds of readmission were nearly four times higher for patients with an SSI (OR 3.78; 95% CI: 1.25–11.39).

Within the SSI group, the mean time to the development of infection symptoms was 5.8 days (±2.4). Clinical signs were highly prevalent: purulent drainage occurred in 83.0% of cases, warmth or swelling in 76.6%, delayed wound healing in 72.3%, and pain or tenderness in 68.1%. These symptoms not only serve as critical diagnostic clues but also signify the significant morbidity associated with SSIs.

Overall, these results underscore the multifaceted risk profile for SSIs, encompassing demographic factors such as age, gender, socioeconomic status, and rural residence, as well as clinical factors like BMI and operative duration. The consequences are profound, leading to prolonged hospital stays, delayed recovery, and higher readmission rates. Targeted interventions to reduce operative time, optimize perioperative care in higher-risk individuals (particularly those with elevated BMI and socioeconomic challenges), and close postoperative monitoring could help mitigate these significant postoperative complications.

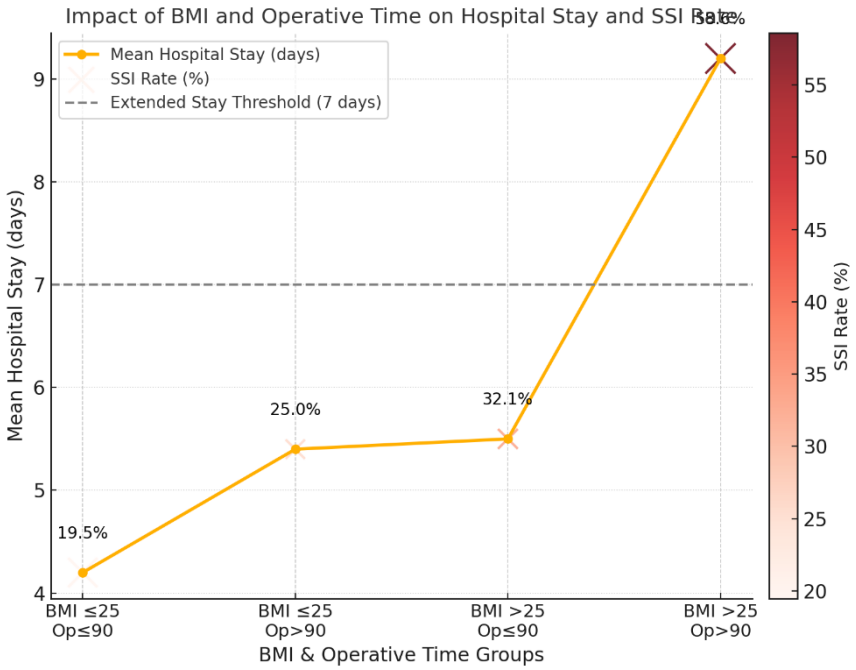

Figure 1 BMI Impact and Operative Time on Hospital Stay

This figure displays the relationship between mean hospital stay (line/points, y-axis) and combined BMI and operative time groups (x-axis), with each group's SSI rate represented as a bubble (color intensity and size proportional to group size). A dotted line marks the 7-day threshold for prolonged hospitalization, aiding in rapid identification of high-risk groups. The group with both elevated BMI (>25 kg/m^2) and prolonged operative time (>90 min) demonstrates not only the highest mean hospital stay but also the highest SSI rate. SSI rates and hospital stay both trend upward as risk factors accumulate, supporting the inference that these factors synergistically worsen clinical outcomes. The visual layering of hospital stay, SSI rate, and group size enables quick identification of patient subgroups that may benefit from targeted infection control and perioperative interventions. This visualization provides actionable insights by showing how modifiable factors—BMI and operative duration—interact to impact postoperative courses, with clear implications for preoperative risk stratification and surgical planning.

DISCUSSION

This study highlights a markedly elevated frequency of surgical site infection (SSI) following open appendectomy in patients with complicated appendicitis, with a rate of 34.3%, substantially exceeding the global pooled SSI incidence of approximately 7% reported across appendectomy procedures of varying complexity and surgical approach (14). These findings underscore the disproportionate burden of postoperative infections in low-resource settings, particularly where laparoscopic capabilities remain limited and open surgery continues as the standard intervention. The observed frequency aligns with regional literature such as Akbar et al., who reported a 27.5% SSI rate in similar surgical populations in Pakistan (10), but surpasses findings from some comparable environments like the Ethiopian pediatric cohort with a 9.11% rate (15). These variations likely reflect differences in surgical technique, disease

severity, infrastructure, and perioperative protocols. Notably, this study specifically restricted its focus to complicated appendicitis managed through open appendectomy—a group inherently at higher risk due to pre-existing contamination, delayed presentation, and extensive tissue handling.

Several factors were identified as significantly associated with SSI, including male gender, rural residence, low socioeconomic status, higher BMI, and prolonged operative time. The association between male gender and higher SSI incidence, while observed in this cohort, contrasts with larger systematic reviews suggesting no consistent sex-related difference in postoperative complications (16). However, men may present later or with more advanced disease, potentially contributing to this discrepancy. Rural residence emerged as a strong predictor of infection, supporting prior observations that geographic barriers can delay timely care, result in more severe clinical presentations, and contribute to suboptimal perioperative conditions (17). These disparities reinforce the need for equitable healthcare delivery and timely referral systems in rural catchments.

The impact of socioeconomic status on SSI risk is consistent with broader global evidence indicating that low-income individuals face barriers not only to accessing timely care but also to maintaining postoperative hygiene, nutrition, and follow-up adherence (18). The findings also reaffirm the well-established association between elevated BMI and infection risk. Obesity has been shown to impair wound healing through mechanisms such as decreased tissue oxygenation, chronic low-grade inflammation, and altered immune responses (19). This is further exacerbated during open surgery due to increased technical difficulty, longer operative durations, and higher subcutaneous fat burden, all of which were evident in the current study. Prolonged operative time, specifically durations exceeding 90 minutes, was found to independently predict SSI—a finding echoed in prior surgical literature where extended exposure correlates with increased tissue trauma, anesthetic stress, and microbial contamination (20).

The integrated graphical analysis supports these associations by visually demonstrating how combined high BMI and prolonged surgery exponentially increase hospital stay duration and SSI rates. These insights provide both mechanistic understanding and a practical framework for stratifying surgical risk. Clinically, these results advocate for implementing targeted infection prevention strategies—such as tailored antibiotic prophylaxis, perioperative glucose control, shorter operative windows, and post-discharge wound monitoring—particularly in patients with multiple risk factors. Incorporating risk-based protocols may reduce infection rates and associated healthcare costs in resource-constrained settings.

Despite its strengths, including prospective data collection, standardized definitions, and clearly defined risk factor evaluation, the study has limitations that warrant acknowledgment. The single-center nature of the research restricts generalizability, especially to regions with different healthcare infrastructure or surgical practices. The modest sample size, while statistically justified, limits subgroup analysis and precludes multivariate modeling, thereby introducing the possibility of residual confounding. Additionally, potential inter-observer variability in SSI assessment, absence of microbiological profiling, and lack of detailed nutritional or immune status data may have influenced outcome ascertainment. The non-randomized sampling approach further introduces potential selection bias, although the use of consecutive enrollment mitigates this to some extent.

Future studies should aim for multicenter collaboration to enhance external validity and employ larger cohorts that allow for robust multivariable regression and predictive modeling. Investigating the role of perioperative care bundles, nutritional supplementation, and minimally invasive alternatives—where feasible—in mitigating infection risk in complicated appendicitis could yield actionable strategies. The development of SSI prediction scores tailored to LMIC contexts, integrating clinical, demographic, and intraoperative factors, may also guide early risk stratification and targeted prophylaxis. This study contributes meaningful insights into the burden and determinants of surgical site infection in high-risk surgical populations within low-resource environments. By identifying modifiable and context-specific risk factors, it offers a pathway toward evidence-informed surgical care that aligns with global efforts to reduce preventable postoperative complications and optimize surgical outcomes in vulnerable healthcare systems.

CONCLUSION

This study demonstrated a high frequency of surgical site infection (34.3%) among patients undergoing open appendectomy for complicated appendicitis, significantly exceeding global averages and emphasizing the vulnerability of this high-risk group in resource-limited healthcare settings. Key risk factors—including male gender, rural residence, low socioeconomic status, elevated BMI, and prolonged operative time—highlight clinically modifiable targets for improving surgical outcomes. These findings reinforce the need for tailored perioperative infection prevention strategies, equitable access to timely surgical care, and enhanced postoperative monitoring in similar healthcare environments. From a research standpoint, the results underscore the importance of developing context-specific risk prediction models and evaluating the efficacy of targeted interventions to mitigate SSI risk in complicated appendicitis, particularly where open surgery remains the primary operative approach.

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