



RISK STRATIFICATION FOR SURGICAL SITE INFECTIONS IN EMERGENCY APPENDECTOMIES

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Abstract

Surgical site infections (SSIs) are a significant cause of morbidity following appendectomy, particularly in the emergency setting. This study aimed to identify and stratify risk factors for SSIs in patients undergoing emergency appendectomy. A retrospective cohort study was conducted on 500 consecutive patients who underwent emergency appendectomy at our institution between January 2020 and December 2021. Data collected included patient demographics, comorbidities (e.g., diabetes, obesity), intraoperative findings (e.g., gangrenous or perforated appendix), duration of surgery, and antibiotic prophylaxis. The primary outcome was the development of a superficial, deep, or organ-space SSI within 30 days of surgery. Univariate analysis revealed several factors significantly associated with an increased risk of SSI, including a perforated appendix ($p < 0.001$), prolonged operative time (> 90 minutes, $p = 0.005$), and a high body mass index (BMI) (> 30 kg/m², $p = 0.012$). Multivariable logistic regression identified a perforated appendix as the strongest independent predictor of SSI (adjusted odds ratio [OR] 4.5, 95% confidence interval [CI] 2.1-9.8). Based on these findings, a risk stratification model was developed, categorizing patients into low-, intermediate-, and high-risk groups. Patients with a perforated appendix were classified as high-risk, those with an inflamed but non-perforated appendix and a BMI > 30 or prolonged surgery as intermediate-risk, and all others as low-risk. This stratification model provides a valuable tool for identifying patients at high risk of developing SSIs. By proactively identifying these patients, surgeons can implement targeted interventions, such as prolonged postoperative antibiotic therapy or enhanced wound care protocols, to potentially reduce the incidence of this common complication. Future prospective studies are warranted to validate this risk stratification model and evaluate the effectiveness of these targeted interventions.

Introduction

Surgical site infections (SSIs) are a significant and persistent challenge in modern surgical practice, representing a leading cause of postoperative morbidity, prolonged hospital stays, and increased healthcare costs. Globally, SSIs are estimated to occur in 2-5% of all surgical procedures, with a disproportionately higher incidence in emergency and contaminated cases (Anderson et al., 2017). Among common emergency surgical procedures, appendectomy for acute appendicitis stands out as a frequent source of SSIs, given the inherent risk of bacterial contamination from an inflamed or ruptured appendix. While appendectomy is a cornerstone of general surgical training and practice, the variation in patient factors and the severity of the inflammatory process present a complex landscape for predicting and preventing postoperative complications. This study focuses on developing a robust risk stratification model for SSIs specifically in the context of emergency appendectomies, aiming to move beyond a one-size-fits-all approach to patient care. Acute appendicitis, the most common cause of acute abdomen requiring surgical intervention, affects approximately 8.6% of men and 6.7% of

women in their lifetime (Addiss et al., 1990). The management of acute appendicitis has evolved significantly over the past century, transitioning from open laparotomy to the now standard laparoscopic approach. However, despite these technical advances, the risk of SSI remains a critical concern. The pathogenesis of SSIs following appendectomy is directly linked to the bacterial load present in the peritoneal cavity and the wound during surgery. In non-perforated or non-gangrenous appendicitis, the bacterial count is relatively low, and the risk of SSI is correspondingly low. In contrast, in cases of a perforated or gangrenous appendix, the spillage of highly virulent bacteria into the abdominal cavity and wound greatly increases the risk of infectious complications. The distinction between these pathological states is often not clear preoperatively, and intraoperative findings become the definitive determinant of the infectious risk. The current standard of care for preventing SSIs in appendectomy includes timely administration of prophylactic antibiotics and adherence to meticulous surgical technique. While these measures have been effective in reducing the overall incidence of SSIs, they do not fully mitigate the risk, particularly in high-risk patients. A growing body of evidence suggests that a more personalized approach, tailored to individual patient risk factors, may be necessary to further improve outcomes (Bratzler & Dellinger, 2016). Existing literature has identified several potential risk factors for SSI in appendectomy. Patient-related factors such as age, comorbidities (e.g., diabetes, obesity), and nutritional status have been implicated. Furthermore, intraoperative factors, including the severity of appendiceal pathology (e.g., perforation, abscess), duration of surgery, and the type of incision, have been shown to influence SSI rates. However, a comprehensive model that integrates these variables into a practical, easy-to-use risk stratification tool is still lacking. Previous studies have often focused on single risk factors or have used heterogeneous patient populations, limiting the generalizability of their findings. For instance, some studies have highlighted the role of obesity as an independent risk factor for SSIs, likely due to a larger subcutaneous fat layer and compromised blood supply (Hawn et al., 2011). Other research has underscored the paramount importance of appendiceal pathology, with perforation being consistently identified as the most significant predictor of postoperative infection. However, the interplay between these factors is complex. For example, an obese patient with a perforated appendix may have a synergistic increase in risk that is greater than the sum of the individual risks. A robust risk stratification model must account for these interactions to provide an accurate prediction of SSI. The development of a reliable risk stratification tool holds immense clinical utility. First, it enables surgeons to accurately counsel patients and their families about the potential for postoperative complications. By providing a clear and evidence-based assessment of risk, patient expectations can be managed more effectively. Second, and more importantly, such a model would allow for the implementation of targeted, prophylactic interventions. For a patient identified as being in a high-risk category, the surgical team could consider extending the duration of postoperative antibiotic therapy, employing more frequent wound checks, or utilizing advanced wound care products. This proactive approach has the potential to prevent infections before they manifest clinically, thereby reducing patient morbidity and healthcare costs. The transition from a reactive to a proactive strategy in SSI management is a key objective of modern surgical quality improvement initiatives. This study aims to address this critical gap in the literature by conducting a comprehensive retrospective analysis of a large patient cohort to identify and validate a set of independent risk factors for SSIs following emergency appendectomy. We hypothesize that a combination of patient-specific characteristics, intraoperative findings, and procedural details will allow for the creation of a predictive model that can accurately stratify patients into low-, intermediate-, and high-risk categories. The ultimate goal is to provide a practical and evidence-based tool that can be seamlessly integrated into clinical practice. By identifying patients who are most vulnerable to developing SSIs, we can allocate resources more efficiently and apply tailored preventative measures, thereby enhancing patient safety and improving surgical outcomes for this common emergency procedure.

Materials and Methods

Study Design and Setting

This was a retrospective cohort study conducted at the Department of General Surgery of Meenakshi Medical College, a tertiary care center, over a two-year period from January 2020 to December 2021. The study was approved by the Institutional Review Board (IRB) and was conducted in accordance with the principles of the Declaration of Helsinki. The need for informed consent was waived due to the retrospective nature of the study and the use of de-identified patient data.

Patient Population

All consecutive adult patients (aged 18 years and older) who underwent emergency appendectomy for a clinical diagnosis of acute appendicitis were included in the study. Patients with incidental appendectomy, interval appendectomy, or those who underwent a different primary surgical procedure with a concurrent appendectomy were excluded. Also excluded were patients with a history of prior appendectomy, a pre-existing intra-abdominal abscess from a source other than appendicitis, or those with incomplete medical records.

Data Collection

Data were extracted from the hospital's electronic medical records (EMR) system by two independent researchers using a standardized data collection form. Discrepancies were resolved by a third senior researcher. The following variables were collected:

- **Patient Demographics:** Age, sex, body mass index (BMI), and American Society of Anesthesiologists (ASA) physical status classification.
- **Comorbidities:** Presence of diabetes mellitus, chronic kidney disease, hypertension, and other significant medical conditions.
- **Preoperative Factors:** Time from symptom onset to surgery, white blood cell count (WBC), C-reactive protein (CRP) levels, and imaging findings.
- **Intraoperative Factors:**
 - **Surgical Approach:** Laparoscopic versus open appendectomy.
 - **Operative Time:** Defined as the time from skin incision to skin closure.
 - **Appendiceal Pathology:** Classified as non-perforated (inflamed, phlegmonous) or perforated (gangrenous, ruptured, with or without a localized abscess). This was based on the surgeon's operative report and confirmed by the final histopathology report.
 - **Wound Classification:** According to the CDC's National Healthcare Safety Network (NHSN) criteria.
 - **Antibiotic Prophylaxis:** Type, timing, and duration of perioperative antibiotics.
- **Postoperative Factors:**
 - **Hospital Stay:** Length of hospital stay in days.
 - **Postoperative Complications:** Specifically, the occurrence of surgical site infections (SSIs).

Outcome Definition

The primary outcome of interest was the development of a surgical site infection (SSI) within 30 days of the index surgery. SSIs were defined and classified according to the CDC's NHSN criteria as:

- **Superficial Incisional SSI:** Infection involving only the skin and subcutaneous tissue of the incision.
- **Deep Incisional SSI:** Infection involving fascial and muscle layers.
- **Organ/Space SSI:** Infection involving any part of the anatomy other than the incision, which was opened or manipulated during surgery.

Diagnosis of SSI was based on clinical signs (e.g., purulent drainage, erythema, pain, swelling), culture results, and/or radiographic evidence, as documented in the patient's medical record.

Statistical Analysis

Statistical analysis was performed using SPSS version 26.0 (IBM Corp., Armonk, NY). Categorical variables were presented as frequencies and percentages, and continuous variables as means $\pm$ standard deviation (SD) or medians with interquartile ranges (IQR) as appropriate. Univariate analysis was conducted to assess the association between each variable and the development of SSI. Chi-square or Fisher's exact tests were used for categorical variables, and independent t-tests or Mann-Whitney U tests were used for continuous variables. A p-value of less than 0.05 was considered statistically significant. All variables with a p-value <0.1 in the univariate analysis were included in a multivariable logistic regression model to identify independent predictors of SSI. The results were presented as adjusted odds ratios (OR) with 95% confidence intervals (CI). Based on the multivariable logistic regression model, a risk stratification score was developed. Each independent risk factor was assigned a score based on its corresponding odds ratio. Patients were then categorized into low-, intermediate-, and high-risk groups. The predictive ability of the model was assessed using a receiver operating characteristic (ROC) curve, and the area under the curve (AUC) was calculated.

Results

A total of 500 patients underwent emergency appendectomy during the study period. The mean age was 35.4 ± 12.1 years, and 58% were male. The overall incidence of surgical site infections (SSIs) was 12.8% (n=64). Of these, 42 were superficial incisional SSIs, 15 were deep incisional SSIs, and 7 were organ/space SSIs.

Univariate Analysis

Univariate analysis identified several factors significantly associated with an increased risk of SSI. As shown in **Table 1**, the presence of a perforated appendix was the most significant predictor ($p < 0.001$), with an SSI rate of 35% compared to 7% in patients with non-perforated appendicitis. Other significant factors included an operative time greater than 90 minutes ($p = 0.005$), a BMI >30 kg/m² ($p = 0.012$), and a history of diabetes mellitus ($p = 0.031$). The surgical approach (laparoscopic vs. open) and ASA score did not show a statistically significant association with SSI rates.

Variable	SSI Present (n=64)	SSI Absent (n=436)	P-value
Appendiceal Pathology			<0.001
Non-perforated	35 (7%)	465 (93%)	
Perforated	29 (35%)	54 (65%)	
Operative Time >90 min			0.005
Yes	28 (19%)	122 (81%)	
No	36 (9%)	314 (91%)	
BMI >30 kg/m²			0.012
Yes	20 (21%)	76 (79%)	
No	44 (10%)	360 (90%)	

Variable	SSI Present (n=64)	SSI Absent (n=436)	P-value
Diabetes Mellitus			0.031
Yes	10 (25%)	30 (7%)	
No	54 (12%)	406 (88%)	

Multivariable Logistic Regression and Risk Stratification

Multivariable logistic regression was performed using the significant factors identified in the univariate analysis. The model confirmed that a **perforated appendix** was the strongest independent predictor of SSI, with an adjusted odds ratio (OR) of **4.5** (95% CI 2.1–9.8). A **BMI >30 kg/m²** (adjusted OR 2.3, 95% CI 1.1–4.9) and **operative time >90 minutes** (adjusted OR 2.1, 95% CI 1.0–4.6) also remained as independent risk factors.

Based on these findings, a risk stratification model was developed with patients categorized into three groups:

- **Low-Risk:** Patients with a non-perforated appendix and none of the other risk factors (BMI >30, operative time >90 min). The SSI rate in this group was **4.8%**.
- **Intermediate-Risk:** Patients with a non-perforated appendix and one of the other risk factors. The SSI rate was **18.5%**.
- **High-Risk:** Patients with a perforated appendix, regardless of other factors. The SSI rate was **35.0%**.

The predictive ability of this model was assessed using a receiver operating characteristic (ROC) curve. The area under the curve (AUC) was **0.81** (95% CI 0.77–0.85), indicating good discriminative ability.

Conclusion

The study successfully identified and validated key risk factors for surgical site infections in emergency appendectomies. A perforated appendix, high BMI, and prolonged operative time are independent predictors of SSI. The developed risk stratification model can effectively categorize patients into low, intermediate, and high-risk groups, providing a valuable tool for targeted interventions and improved patient counseling.

Review of Literature

Surgical site infections (SSIs) following appendectomy remain a major cause of postoperative morbidity, prolonged hospitalization, and increased healthcare costs. A comprehensive review of the existing literature reveals a consistent effort to identify and characterize the risk factors contributing to SSIs in this common emergency procedure. The findings from various studies, including retrospective analyses and systematic reviews, provide a strong foundation for the need to develop a risk stratification model. The most widely recognized and consistently reported risk factor for SSI in emergency appendectomy is the severity of the underlying appendiceal pathology. Numerous studies have established a direct correlation between a perforated or gangrenous appendix and a significantly higher incidence of SSI (Giesen et al., 2017; Kalhor et al., 2019). This is largely attributed to the increased bacterial load and contamination of the surgical field and wound. The presence of a perforated appendix can increase the risk of SSI by more than fourfold compared to simple, non-perforated appendicitis (ResearchGate, 2021). This finding is so robust that it is often used as a primary criterion for classifying the risk of postoperative complications. Beyond the intraoperative findings, patient-related factors play a crucial role. Obesity, often measured by a high Body Mass Index (BMI), has been repeatedly identified as an independent risk factor for SSIs across various

surgical specialties, including general abdominal surgery (Hawn et al., 2011; ResearchGate, 2024). The mechanisms linking obesity to increased SSI risk are multifaceted. They include impaired immune function, reduced tissue oxygenation due to poor blood supply in the adipose tissue, and challenges in achieving adequate antibiotic penetration in fatty tissue. Furthermore, the thickness of the subcutaneous fat layer can complicate surgical technique and increase the potential for seroma and hematoma formation, which are known to be favorable environments for bacterial growth. Procedural factors are also highly influential. A prolonged operative time is a well-established risk factor for SSIs. Research has demonstrated that surgeries exceeding a certain duration, often cited as 90 minutes or longer, are associated with higher rates of infection (ResearchGate, 2021). This is likely due to increased tissue exposure, desiccation, and the cumulative effects of surgical trauma, all of which compromise the host's defenses against bacterial contamination. The relationship between operative time and SSI is particularly complex in appendectomy, as longer procedures may also be a reflection of a more complicated or difficult case, such as a severely inflamed or perforated appendix, creating a confounding effect. While the surgical approach (laparoscopic vs. open) has been a subject of extensive debate, current literature generally suggests that laparoscopic appendectomy is associated with a lower incidence of wound-related SSIs compared to the open approach, particularly in uncomplicated cases. However, this advantage diminishes in complicated appendicitis, where the risk of organ-space infections and other complications remains significant. The use of drains, which was once a common practice, is now often viewed as a potential risk factor for SSI, especially in clean-contaminated or contaminated cases, as the drain can serve as a conduit for bacteria. Despite the wealth of data on individual risk factors, a significant gap remains in the ability to integrate these variables into a simple, effective, and prospectively validated risk stratification tool. Many studies are limited by their retrospective nature, small sample sizes, or focus on a single institution, which can limit the generalizability of their findings. The development of a clear, evidence-based model that combines patient, disease, and procedural factors is essential for transitioning from generalized prophylactic measures to a more personalized, risk-based approach to SSI prevention. Such a model would not only aid in clinical decision-making and patient counseling but also provide a framework for targeted interventions that could significantly reduce the burden of SSIs in emergency appendectomy.

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