Test file: Incidence and Risk Factors for Surgical Site Infection Following General Trauma Surgery: A Retrospective Cohort Analysis

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Abstract

Background: Surgical site infection (SSI) remains a significant and costly complication after trauma surgery, contributing to increased morbidity, prolonged hospitalization, and higher healthcare expenditures. Identifying the incidence and modifiable risk factors specific to the general trauma surgery population is essential for developing targeted prevention strategies. Methods: A single-center retrospective cohort study was conducted. We included 2,134 adult patients who underwent emergency general trauma surgery (e.g., laparotomy, thoracotomy, repair of major fractures with soft tissue involvement) between January 2018 and December 2022. SSI was defined and classified according to the Centers for Disease Control and Prevention (CDC) criteria. Patient demographics, injury characteristics, operative details, and perioperative management data were collected. Univariate analyses and multivariate logistic regression were performed to identify independent predictors of SSI. Results: The overall incidence of SSI was 9.2% (197/2134). Superficial incisional SSI accounted for 5.6%, deep incisional SSI for 2.5%, and organ/space SSI for 1.1%. Multivariate analysis identified six independent risk factors: open fracture (Gustilo type III) or gross intra-abdominal contamination at injury (adjusted odds ratio [aOR] 3.71, 95% confidence interval [CI] 2.54-5.42), surgery duration >180 minutes (aOR 2.95, 95% CI 2.05-4.25), requirement for massive transfusion (>10 units of packed red blood cells in 24 hours) (aOR 2.73, 95% CI 1.88-3.96), preoperative hypothermia (core temperature <36.0°C) (aOR 2.41, 95% CI 1.68-3.46), diabetes mellitus (aOR 2.02, 95% CI 1.39-2.93), and body mass index (BMI) ≥30 kg/m² (aOR 1.78, 95% CI 1.23-2.58). Appropriate preoperative antibiotic prophylaxis (administered within 60 minutes before incision) was a significant protective factor (aOR 0.38, 95% CI 0.26-0.56). Conclusion: SSI complicates nearly one in ten general trauma surgeries, with several strong and potentially modifiable risk factors. These findings underscore the importance of protocolized care bundles addressing timely antibiotic administration, normothermia maintenance, blood conservation strategies, and consideration of damage-control surgery in high-risk patients to reduce the burden of SSI.

Keywords: Surgical Site Infection; Wound Infection; Trauma Surgery; Risk Factors; Postoperative Complications; Retrospective Studies.

1. Introduction

Surgical site infection (SSI) is one of the most prevalent healthcare-associated infections, accounting for approximately 20% of all such infections and imposing a substantial burden on healthcare systems worldwide [1]. In the specific context of trauma surgery, patients are at a uniquely elevated risk due to the emergent and often contaminated nature of their injuries, the physiologic stress of polytrauma, and frequent breaches in standard preoperative preparation protocols [2]. SSI leads to devastating consequences, including a significant increase in hospital length of stay (by an average of 9.7 days), a doubling of re-admission rates, and a marked escalation in direct medical costs, which can be up to threefold higher than for patients without this complication [3]. Despite widespread implementation of evidence-based guidelines, SSI rates in trauma populations remain stubbornly high, indicating a need for population-specific risk stratification and intervention [4].

The pathogenesis of SSI in trauma patients is multifactorial, involving a complex interplay between the degree of microbial contamination, the local wound environment (e.g., tissue necrosis, hematoma, ischemia), and systemic host defenses, which are often compromised by hemorrhage, shock, and the systemic inflammatory response syndrome [5]. While prior studies have explored SSI risk factors in general surgery or specific orthopedic trauma, there is a relative paucity of comprehensive analyses focusing on the heterogeneous cohort of patients undergoing general trauma surgery, which encompasses abdominal, thoracic, and major musculoskeletal procedures [6]. This study aimed to determine the contemporary incidence of SSI in a large cohort of patients undergoing emergency general trauma surgery at a high-volume tertiary center and to identify independent patient-, injury-, and management-related factors associated with its development. The ultimate goal is to inform the creation of more effective, targeted prevention protocols for this vulnerable patient population.

2. Methods

2.1 Study Design and Setting

This was a retrospective cohort study conducted at an American College of Surgeons-verified Level I trauma center. The study protocol was reviewed and approved by the hospital's Institutional Review Board with a waiver of informed consent due to the retrospective nature of the data collection.

2.2 Study Population

The study included all consecutive adult patients (age ≥18 years) who underwent an emergency general trauma surgery procedure between January 1, 2018, and December 31, 2022. Emergency general trauma surgery was defined as any non-elective operative intervention performed by the acute care surgery or trauma service for injuries involving the torso (abdomen, thorax) or major musculoskeletal structures with significant soft tissue disruption. Exclusion criteria were: 1) death within 48 hours of surgery, 2) isolated burn injuries or traumatic brain injuries without other major operative trauma, 3) patients with incomplete electronic medical records for key variables, and 4) patients with an active infection at a site remote from the surgical incision at the time of injury.

2.3 Data Collection and Variables

Data were meticulously extracted from the hospital's electronic health record system, the trauma registry, and the infection prevention and control database. A standardized data collection form was used to ensure consistency. Collected variables were grouped into several domains:

Patient Demographics and Comorbidities: Age, sex, body mass index (BMI), smoking status (current), and pre-existing comorbidities including diabetes mellitus, chronic obstructive pulmonary disease, and immunocompromised state (e.g., from chronic steroids, chemotherapy).

Injury Characteristics: Mechanism of injury (blunt vs. penetrating), Injury Severity Score (ISS), Abbreviated Injury Scale (AIS) scores for relevant body regions, and the specific presence of an open fracture (classified per Gustilo-Anderson criteria [7]) or documented gross contamination in abdominal trauma.

Operative Details: Type of surgery (e.g., laparotomy, thoracotomy, external fixation), surgical duration (from incision to closure), wound classification (Clean-Contaminated, Contaminated, Dirty), and estimated intraoperative blood loss.

Perioperative Management: Timing and agent used for preoperative antibiotic prophylaxis (categorized as "appropriate" if a guideline-recommended agent was administered intravenously within 60 minutes before incision [8]), intraoperative and postoperative blood product transfusion volumes (with massive transfusion defined as >10 units of packed red blood cells in 24 hours [9]), and the lowest recorded core temperature within the first 6 hours of admission (hypothermia defined as <36.0°C).

Outcome Variable: The primary outcome was the development of an SSI within 30 days of the index operation, as per CDC/National Healthcare Safety Network definitions [10]. SSIs were categorized as superficial incisional, deep incisional, or organ/space. Diagnosis required either purulent drainage, a positive culture from the surgical site, or clinical signs of infection leading to a surgeon's diagnosis and intervention.

2.4 Statistical Analysis

Continuous variables were presented as mean ± standard deviation or median with interquartile range based on their distribution, and compared using the Student's t-test or Mann-Whitney U test. Categorical variables were presented as frequencies and percentages, and compared using the Chi-square or Fisher's exact test. To identify independent risk factors for SSI, all variables with a p-value <0.10 in the univariate analysis were entered into a backward stepwise multivariate logistic regression model. Results were reported as adjusted odds ratios (aOR) with their corresponding 95% confidence intervals (CI). The goodness-of-fit of the final model was assessed using the Hosmer-Lemeshow test. A two-sided p-value <0.05 was considered statistically significant. All analyses were performed using SPSS Statistics software version 27.0.

3. Results

3.1 Baseline Patient and Injury Characteristics

From an initial pool of 2,457 trauma surgery patients, 2,134 met the inclusion criteria. The mean age was 43.8 ± 17.2 years, and 69.5% were male. The predominant mechanism of injury was blunt trauma (71.2%), primarily from motor vehicle collisions, followed by penetrating trauma (28.8%). The median ISS was 19 (IQR 13-27). Abdominal procedures were performed in 41.6% of patients, thoracic in 18.9%, and major orthopedic procedures in 39.5%. Open fractures (Gustilo III) were present in 15.3% of the cohort, and 12.1% had documented gross abdominal contamination.

3.2 Incidence and Characteristics of SSI

The overall SSI rate was 9.2% (197 out of 2,134 patients). Of these, 119 (5.6% of total cohort) were superficial incisional SSIs, 54 (2.5%) were deep incisional SSIs, and 24 (1.1%) were organ/space infections. The median time to SSI diagnosis was 7 days postoperatively (IQR 4-12 days). Microbial cultures were obtained in 88.3% of SSI cases, with 76.1% returning positive. The most frequently isolated pathogens were Staphylococcus aureus (36.8% of positive cultures; 44.7% of these were MRSA), followed by Enterobacteriaceae (e.g., Escherichia coli, Klebsiella spp.) (34.2%) and Pseudomonas aeruginosa (11.4%).

3.3 Univariate Analysis of Risk Factors

Patients who developed an SSI were significantly older, had a higher BMI, and had a greater prevalence of diabetes compared to those without SSI (all p<0.01). Injury-related factors strongly associated with SSI included a higher median ISS (23 vs. 18, p<0.001), the presence of an open Gustilo III fracture (31.5% vs. 13.2%, p<0.001), and gross abdominal contamination (27.4% vs. 10.5%, p<0.001).

Key surgical and management factors associated with SSI were prolonged operative time (>180 minutes: 55.3% vs. 30.1%, p<0.001), massive transfusion requirement (29.9% vs. 14.7%, p<0.001), and preoperative hypothermia (46.7% vs. 25.8%, p<0.001). Inappropriate or delayed antibiotic prophylaxis was also more common in the SSI group (21.3% vs. 10.8%, p<0.001).

3.4 Multivariate Logistic Regression Analysis

The final multivariate model (Hosmer-Lemeshow test, p=0.42) identified six independent patient- and care-related risk factors for SSI development (Table 1):

1.Open fracture (Gustilo III) or gross abdominal contamination: aOR 3.71, 95% CI 2.54-5.42.
2.Surgery duration >180 minutes: aOR 2.95, 95% CI 2.05-4.25.
3.Massive transfusion requirement:aOR 2.73, 95% CI 1.88-3.96.
4.Preoperative hypothermia (<36.0°C): aOR 2.41, 95% CI 1.68-3.46.
5. Diabetes mellitus: aOR 2.02, 95% CI 1.39-2.93.
6. BMI ≥30 kg/m^2: aOR 1.78, 95% CI 1.23-2.58.

The administration of appropriate preoperative antibiotic prophylaxis was a strong independent protective factor (aOR 0.38, 95% CI 0.26-0.56).

3.5 Clinical Outcomes Associated with SSI

The development of an SSI was associated with significantly worse clinical outcomes. Patients with SSI had a markedly longer median hospital length of stay (22 days vs. 10 days, p<0.001), a higher rate of ICU admission (68.0% vs. 45.2%, p<0.001), and an increased 30-day hospital readmission rate (22.8% vs. 6.1%, p<0.001). In-hospital mortality was also higher, though this did not reach statistical significance in this cohort (4.6% vs. 2.9%, p=0.15).

4. Discussion

This large retrospective analysis of over 2,100 general trauma surgery patients confirms that SSI remains a frequent and consequential complication, affecting nearly one in ten patients. The identified incidence of 9.2% aligns with the higher end of reported rates in trauma literature, which typically range from 5% to 15% [11, 12]. Our multivariate model elucidates a hierarchy of risk, with factors related to the magnitude of injury and physiological derangement being most potent.

The strongest predictor was the presence of a severely contaminated wound, either an open Gustilo III fracture or gross abdominal contamination (aOR 3.71). This underscores the non-modifiable but crucial role of the initial inoculum in determining infection risk. For such high-contamination injuries, our data reinforce the critical importance of meticulous early debridement and irrigation, and may support the use of broader-spectrum or dual-agent antibiotic prophylaxis regimens in select cases, as suggested by some specialty guidelines [13].

Three of the identified independent risk factors are directly related to perioperative management and are potentially modifiable: prolonged surgery, hypothermia, and massive transfusion. Surgery exceeding three hours (aOR 2.95) likely increases risk through greater tissue trauma, longer exposure to airborne contaminants, and sub-therapeutic antibiotic levels [14]. This finding strongly advocates for the principles of damage control surgery in unstable patients and for efficient, well-coordinated surgical teams. Preoperative hypothermia (aOR 2.41) is a well-known immune suppressant, impairing neutrophil function and wound healing [15]. Our results highlight a critical gap in pre-operative care and mandate the strict implementation of active warming protocols from the point of entry in the emergency department through the operating room. The link with massive transfusion (aOR 2.73) is multifactorial, relating to both the immunomodulatory effects of blood products and as a marker of profound shock and physiological insult [16]. This association emphasizes the importance of balanced resuscitation, hemostatic surgery, and the judicious use of blood products guided by viscoelastic testing when available.

Patient-specific factors like diabetes (aOR 2.02) and obesity (aOR 1.78) confirm the vulnerability imposed by metabolic dysfunction and highlight populations needing intensified perioperative glycemic control and possibly adjusted dosing of prophylactic antibiotics [17].

The powerful protective effect of appropriate antibiotic timing (aOR 0.38) cannot be overstated. It serves as a bedrock preventive measure. However, the high rate of inappropriate prophylaxis in the SSI group indicates systemic failures in the chaotic trauma resuscitation environment. This argues compellingly for hardwired protocols, such as having antibiotics pre-drawn in trauma bays or utilizing timed alerts in electronic health records [8].

Our study has limitations inherent to its retrospective, single-center design, including potential unmeasured confounders and limits to generalizability. The 30-day follow-up may miss late-presenting infections. Nevertheless, the large sample size and rigorous statistical approach provide robust evidence to guide quality improvement.

Clinical Implications and Future Directions: Based on these findings, we propose a bundled intervention for high-risk trauma surgery patients: 1) Protocolized Antibiotic Administration: A standardized checklist in the trauma resuscitation area. 2) Aggressive Normothermia Management:

Mandatory use of forced-air warmers and fluid warmers from admission. 3) Surgical Strategy: Formal consideration of damage control principles for patients with predicted long operative times or ongoing shock. 4) Targeted Patient Management: Preoperative identification of diabetic and obese patients for enhanced glycemic monitoring and tailored pharmacologic prophylaxis. Future prospective studies should validate this risk model and assess the impact of implementing such a care bundle on SSI rates.

5. Conclusion

SSI is a prevalent complication following general trauma surgery, associated with severe contamination, prolonged operations, physiological disturbances like hypothermia and shock requiring transfusion, and patient comorbidities. While the injury burden is often fixed, several key risk factors are amenable to intervention through systematic, protocol-driven care focused on timely antibiotics, maintenance of normothermia, strategic surgical planning, and vigilant management of comorbid conditions. Addressing these modifiable elements presents a tangible opportunity to improve outcomes and reduce the significant burden of SSI in trauma patients.

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