Test file: The Role of Early Antibiotic Administration in Reducing Surgical Site Infections in Open Fracture Trauma Patients

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Abstract

Objective: To determine the optimal timing of antibiotic administration and its impact on surgical site infection (SSI) rates in patients with open fractures. Methods: A retrospective cohort study was conducted involving 426 patients with grade I–III open fractures admitted to a Level 1 trauma center between January 2019 and December 2023. Patients were stratified into two groups based on the time from injury to first antibiotic dose: the early group (≤1 hour, n=218) and the delayed group (>1 hour, n=208). The primary outcome was the incidence of SSI within 30 days postoperatively. Secondary outcomes included the need for revision surgery, length of hospital stay, and 90-day mortality. Results: The early antibiotic group exhibited a significantly lower SSI rate (8.3% vs. 22.1%, P<0.001) compared to the delayed group. Patients in the early group also had a lower rate of revision surgery (5.5% vs. 14.4%, P<0.01), shorter hospital stay (12.4 ± 3.1 days vs. 18.7 ± 4.2 days, P<0.001), and comparable 90-day mortality (2.3% vs. 3.4%, P>0.05). Multivariate regression analysis identified delayed antibiotic administration (>1 hour) as an independent risk factor for SSI (OR=2.89, 95% CI=1.67–5.01, P<0.001). Conclusion: Administration of antibiotics within 1 hour of injury significantly reduces SSI rates and improves clinical outcomes in open fracture trauma patients, supporting current clinical guidelines advocating for prompt antibiotic prophylaxis in this population.

Keywords: Open fracture; Antibiotic prophylaxis; Surgical site infection; Trauma care; Clinical outcomes

1. Introduction

Open fractures, characterized by a break in the skin overlying a fractured bone, are a common and challenging presentation in trauma surgery, accounting for approximately 3–5% of all fractures [1]. These injuries are associated with a high risk of surgical site infection due to direct contamination of the fracture site with environmental pathogens, soft tissue damage, and compromised vascularity [2]. SSIs in open fracture patients can lead to devastating complications, including osteomyelitis, non-union, chronic wound drainage, and the need for multiple revision surgeries, significantly increasing healthcare costs and reducing patient quality of life [3].

Antibiotic prophylaxis is a cornerstone of open fracture management, with the goal of reducing bacterial colonization at the injury site before definitive surgical intervention [4]. Current clinical guidelines, including those from the American Academy of Orthopaedic Surgeons (AAOS) and the Eastern Association for the Surgery of Trauma (EAST), recommend administering systemic antibiotics within 1 hour of injury [5]. However, adherence to this guideline varies widely in clinical practice, with many patients receiving antibiotics beyond the 1-hour window due to delays in prehospital transport, triage, or diagnostic evaluation [6]. Despite the widespread acceptance of early antibiotic use, limited data exist on the direct correlation between antibiotic timing and SSI rates across different open fracture grades, particularly in patients with severe soft tissue damage (grade III fractures) [7].

This study aims to address this gap by evaluating the impact of antibiotic administration timing on SSI rates and other clinical outcomes in a large cohort of open fracture patients. We hypothesize that antibiotic administration within 1 hour of injury will result in a significantly lower incidence of SSI compared to delayed administration, regardless of fracture grade. The findings of this study may reinforce the importance of protocolized antibiotic prophylaxis in trauma care and inform strategies to improve guideline adherence.

2. Materials and Methods

2.1 Study Population

This retrospective cohort study included adult patients (≥18 years old) with grade I–III open fractures, as classified by the Gustilo-Anderson system [8], admitted to the Department of Orthopaedic Trauma at a Level 1 trauma center between January 2019 and December 2023. Inclusion criteria were: (1) open fracture confirmed by clinical examination and radiographic imaging; (2) surgical intervention performed within 24 hours of injury; (3) complete medical records including antibiotic administration time, surgical details, and follow-up data for 30 days postoperatively. Exclusion criteria were: (1) pre-injury antibiotic use within 7 days; (2) known allergy to the study antibiotics (cefazolin or piperacillin-tazobactam); (3) polytrauma patients with an Injury Severity Score (ISS) > 25; (4) patients who died within 48 hours of admission before SSI could be assessed. The study protocol was approved by the institutional review board (IRB No. 2024-0112), and informed consent was waived due to the retrospective nature of the study.

2.2 Antibiotic Administration Protocol

All patients received empiric antibiotic prophylaxis based on institutional guidelines. Grade I and II open fractures were treated with intravenous cefazolin (1 g every 8 hours) for 24–48 hours postoperatively. Grade III open fractures were treated with intravenous piperacillin-tazobactam (3.375 g every 6 hours) for 72 hours, followed by oral antibiotics for a total of 5–7 days, depending on wound status [9]. The primary exposure variable was the time from injury to the first dose of antibiotics, with patients stratified into the early group (≤1 hour) or the delayed group (>1 hour). Antibiotic administration time was determined from prehospital care records, emergency department (ED) nursing notes, and pharmacy administration logs.

2.3 Outcome Measures

The primary outcome was the incidence of SSI within 30 days of surgery, defined according to the Centers for Disease Control and Prevention (CDC) criteria [10]. SSIs were classified as superficial (involving only the skin and subcutaneous tissue) or deep (involving the fascia, muscle, or bone). Secondary outcomes included: (1) the need for revision surgery due to infection or non-union; (2) length of hospital stay; (3) 90-day mortality rate; (4) incidence of osteomyelitis at 6 months follow-up.

2.4 Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD) and compared using the independent samples t-test. Categorical variables were presented as frequencies and percentages, with comparisons performed using the χ^2 test or Fisher's exact test, as appropriate. Multivariate logistic regression analysis was conducted to identify independent risk factors for SSI, adjusting for potential confounders including age, gender, fracture grade, ISS, and time to surgical intervention. A two-tailed P value < 0.05 was considered statistically significant. All statistical analyses were performed using SPSS version 29.0 (IBM Corp., Armonk, NY, USA).

3. Results

3.1 Baseline Characteristics

A total of 426 patients were included in the final analysis, with 218 in the early antibiotic group and 208 in the delayed group. Baseline characteristics were well-balanced between the two groups, including age, gender, fracture grade distribution, mechanism of injury, and ISS (P>0.05 for all comparisons) (Table 1). The most common fracture locations were the tibia/fibula (48.6%) and forearm (22.3%), and the majority of injuries were caused by motor vehicle collisions (39.4%) and falls from height (28.2%).

3.2 Primary Outcome: Surgical Site Infection Rate

The overall SSI rate was 15.0% (64/426) across the entire cohort. The early antibiotic group had a significantly lower SSI rate (8.3%, 18/218) compared to the delayed group (22.1%, 46/208) (χ^2=20.14, P<0.001). Subgroup analysis by fracture grade revealed that the protective effect of early antibiotics was consistent across all Gustilo-Anderson grades: grade I (4.2% vs. 12.5%, P=0.032), grade II (7.8% vs. 19.6%, P=0.008), and grade III (12.1% vs. 28.9%, P=0.003). Deep SSIs (including osteomyelitis) accounted for 62.5% of all infections in the delayed group, compared to 33.3% in the early group (P=0.015).

3.3 Secondary Outcomes

Patients in the early antibiotic group had a significantly lower rate of revision surgery (5.5%, 12/218 vs. 14.4%, 30/208; χ^2=9.76, P=0.002) and shorter mean hospital stay (12.4 ± 3.1 days vs. 18.7 ± 4.2 days; t=-16.23, P<0.001) compared to the delayed group. The 90-day mortality rate was low in both groups and did

not differ significantly (2.3% vs. 3.4%; P=0.412). At 6 months follow-up, the incidence of osteomyelitis was 2.3% in the early group and 7.2% in the delayed group (χ^2=5.82, P=0.016).

3.4 Multivariate Regression Analysis

Multivariate logistic regression analysis identified delayed antibiotic administration (>1 hour) as an independent risk factor for SSI (odds ratio [OR]=2.89, 95% confidence interval [CI]=1.67–5.01, P<0.001). Other independent risk factors for SSI included grade III fracture (OR=3.12, 95% CI=1.85–5.25, P<0.001) and time to surgical intervention > 12 hours (OR=1.98, 95% CI=1.11–3.55, P=0.021). Age, gender, and ISS were not found to be significant predictors of SSI in this cohort.

4. Discussion

This study confirms that the administration of antibiotics within 1 hour of injury significantly reduces the risk of SSI in open fracture trauma patients, supporting current clinical guidelines [10]. The protective effect of early antibiotics was observed across all Gustilo-Anderson fracture grades, highlighting the importance of prompt antibiotic prophylaxis regardless of injury severity. The multivariate regression analysis further established delayed antibiotic administration as an independent risk factor for SSI, even after adjusting for other confounding variables such as fracture grade and time to surgery.

The mechanism by which early antibiotics reduce SSI risk is likely related to the suppression of bacterial colonization at the injury site before the development of a mature biofilm [11]. Open fractures are contaminated with a variety of pathogens, including *Staphylococcus aureus*, *Streptococcus* species, and gram-negative bacilli, which can rapidly multiply and form biofilms within hours of injury [12]. Biofilms are highly resistant to antibiotics and host immune defenses, making them a major contributor to persistent infections and non-union [13]. By administering antibiotics early, before biofilm formation, clinicians can effectively reduce the bacterial load at the injury site, limiting the risk of subsequent infection.

The subgroup analysis revealed that grade III open fractures, which are associated with the highest SSI risk, benefited most from early antibiotic administration. This finding is particularly relevant, as grade III fractures often involve extensive soft tissue loss, vascular compromise, and heavy contamination, making them more susceptible to infection [14]. The reduction in deep SSIs and osteomyelitis in the early antibiotic group is a critical clinical outcome, as these complications are associated with prolonged hospital stays, multiple surgeries, and long-term disability [15].

Despite the clear benefits of early antibiotics, adherence to the 1-hour guideline remains a challenge in clinical practice. Delays in antibiotic administration are often due to prehospital factors such as long transport times, lack of access to antibiotics in the field, and prioritization of other resuscitation measures in critically injured patients [16]. In-hospital delays may occur due to diagnostic uncertainty, antibiotic allergy concerns, or workflow inefficiencies in the ED. Strategies to improve guideline adherence include protocolizing antibiotic administration in prehospital care, implementing ED order sets that trigger automatic antibiotic dosing for open fracture patients, and providing education to trauma teams on the importance of timely prophylaxis [17].

This study has several limitations that should be acknowledged. First, it is a single-center retrospective study, which may limit the generalizability of the results to other trauma centers with different patient populations and antibiotic protocols. Second, the study did not evaluate the impact of different antibiotic regimens or durations on SSI rates, focusing solely on timing of administration. Third, the study lacked data on patient-reported outcomes such as pain, functional status, and quality of life, which are important measures of long-term recovery. Future multicenter prospective randomized controlled trials are needed to confirm these findings and address these limitations.

5. Conclusion

Administration of antibiotics within 1 hour of injury significantly reduces the incidence of surgical site infections and improves clinical outcomes in open fracture trauma patients across all Gustilo-Anderson grades. Delayed antibiotic administration (>1 hour) is an independent risk factor for SSI, highlighting the need for strict adherence to current clinical guidelines. Trauma teams should prioritize prompt antibiotic prophylaxis in the prehospital and emergency department settings to optimize patient outcomes and reduce the burden of infectious complications in open fracture care.

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