KANSAS JOURNAL of MEDICINE

Brief Report | Quality Improvement

Improving Prophylactic Antibiotic Selection for Type 3 Open Fractures in the Trauma Setting

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ABSTRACT

Introduction. The purpose of this quality improvement study was to implement a standardized prophylactic antibiotic protocol for type 3 open fractures and to evaluate changes in both subjective comfort and objective knowledge of open fracture management among trauma team personnel.

Methods. A simplified protocol for antibiotic selection in open fractures was developed and implemented at two regional Level 1 trauma centers. We used pre-intervention surveys to assess participants' ability to select the preferred antibiotic regimen for open fracture clinical scenarios and their comfort with open fracture management. The intervention consisted of instructional posters displayed in trauma bays showing the Gustilo classification for open fractures and the approved prophylactic antibiotic regimen for each fracture type. After a six-week intervention period, unmatched post-education survey responses were compared with pre-intervention responses using Fisher's Exact Test or the Fisher-Freeman-Halton Exact Test, with significance set at $p < 0.05$.

Results. Participants included 16 orthopedic residents and 18 trauma staff members. The proportion of respondents who reported being very comfortable selecting antibiotics for type 3 open fractures increased from 6% to 68% ($p < 0.001$). Correct identification of the preferred antibiotic regimen across three clinical scenarios involving type 3 open fractures increased by an average of 58%, with all improvements reaching statistical significance ($p < 0.001$).

Conclusions. Implementation of a simplified antibiotic prophylaxis protocol, reinforced with instructional posters in the emergency department, significantly improved participants' knowledge and confidence in antibiotic selection for type 3 open fractures. These findings support the adoption of standardized treatment algorithms in trauma care settings.

INTRODUCTION

Open fractures, often the result of high-energy mechanisms, are defined as a bony fragment communicating with the outside environment as the result of soft tissue disruption.[1] The severity of injury has a direct correlation with the risk of post-operative surgical site infection (SSI).[2] Gustilo developed a well-recognized classification system which is widely used in the orthopaedic literature to describe these open fractures and which is the basis for prophylactic antibiotic regimens used for open fractures in the trauma setting.[3,4]

Early antibiotic administration has a well-recognized impact in reducing post-operative SSI in open fractures.[5,6] In this regard, the official recommendation of the American Academy of Orthopaedic Surgeons is for the first dose of antibiotics to be given as soon as feasibly possible, or within three hours of injury.[5,6] Various antibiotic regimens exist for open fracture management, particularly Gustilo type 3 open injuries. Traditionally, a first-generation cephalosporin and an aminoglycoside have been the standard of care, with penicillin added for grossly contaminated farm-related injuries.[4]

At local trauma centers, orthopaedic residents, general surgery residents, and nursing staff reported uncertainty about appropriate antibiotic regimens for type 3 open fractures, particularly when multiple antibiotics were included in a single protocol. This confusion prompted a literature review, which revealed opportunities to improve staff performance and patient outcomes. For example, Redfern et al.[7] showed non-inferior rates of deep SSI with piperacillin/tazobactam for initial antibiotic prophylaxis in type 3 open fractures when compared with previous multi-antibiotic regimens. Similarly, Siebler et al.[8] demonstrated an effective approach for ensuring timely antibiotic administration in patients with open fractures.

Based on these findings, we aimed to improve prophylactic antibiotic selection at our local trauma centers among all health care professionals treating patients with open fractures, with a particular focus on residents in training. The objectives of this quality improvement (QI) study were (1) to implement a simplified, standardized antibiotic protocol for type 3 open fracture management in the trauma setting and (2) to assess changes in both subjective comfort and objective knowledge of open fracture management among orthopaedic residents and non-orthopaedic trauma staff, including general surgery attendings, general surgery residents, and emergency department personnel such as physician assistants and nurses.

METHODS

This study was conducted during the 2021 academic year as a QI initiative by a five-member team of orthopaedic residents, one from each post-graduate year group. The project was approved by the residency program director and deemed by the The University of Kansas Medical Center's institutional review board (IRB) to be a QI study designed to improve trauma personnel compliance with best practices for selecting prophylactic antibiotics in patients with open fractures.

Classic QI methodology was applied to define, measure, analyze, improve, and control prophylactic antibiotic administration for type 3 open fractures in the trauma setting. The residency QI program methods and previous studies have been described in detail elsewhere.[9]

Development of a standardized antibiotic regimen for open fracture management was modeled after a previously successful protocol implemented at another academic medical center.[8] Antibiotic selection and dosing for the current protocol were determined in collaboration with infectious disease specialists and pharmacists from both regional Level 1 trauma centers.

Orthopaedic residents at all levels of training and non-orthopaedic trauma staff members, including general surgery trauma attendings, general surgery residents, physician assistants, and nursing personnel, were recruited to participate in this QI initiative. Participant comfort with and baseline knowledge of open fracture management were assessed using a 10-question paper pre-intervention survey.

The primary intervention consisted of two educational posters: one displaying the Gustilo open fracture classification system and another outlining the standardized open fracture treatment protocol (Figure 1). Each poster was displayed in the trauma bays at both trauma centers for six weeks. Informal discussions about antibiotic prophylaxis and fracture classification occurred among orthopaedic residents and some non-orthopaedic participants, though these were not considered an essential component of the educational intervention. Following the six-week exposure period, post-intervention survey responses were collected. Pre- and post-surveys were unmatched and anonymous.

A

Gustilo Classification	Injury Description
Type I Fracture	Open fracture with clean wound <1 cm long
Type II Fracture	Open fracture with laceration > 1 cm but <10 cm long Moderate soft tissue damage
Type III A Fracture	Open fracture with laceration >10 cm long Extensive soft tissue damage Segmental or highly comminuted fracture Traumatic amputation
Type III B Fracture	Same as Type 3A fracture but with additional periosteal stripping and bone exposure requiring flap coverage
Type III C Fracture	Any open fracture with vascular injury requiring repair

B

OPEN FRACTURE ANTIBIOTIC PROTOCOL

	Preferred Therapy	Severe Penicillin or Cephalosporin allergy
Type 1 or 2 fracture	Cefazolin 2g IV (<120kg) Cefazolin 3g IV (>120kg)	Clindamycin 900mg
Type 3 fracture (clean)	Piperacillin/Tazobactam 4.5g IV over 4 hours	Levofloxacin 500mg IV
Type 3 fracture (contaminated)	Piperacillin/Tazobactam 4.5g IV over 4 hours	Levofloxacin 500mg IV PLUS Metronidazole 500mg IV
Known MRSA Colonization	Add vancomycin 15 mg/kg q12h	

ORTHOPEDIC SURGERY RESIDENCY PROGRAM OPEN FRACTURE ANTIBIOTIC PROTOCOL
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Figure 1. (A) Gustilo classification for open fractures and (B) open fracture prophylactic antibiotic protocol by Gustilo fracture type. Traumatic amputation may be considered type III C open fractures.

Questionnaire responses were manually entered into the Research Electronic Data Capture (REDCap®) system.[10,11] Responses were compared with the Fisher-Freeman-Halton Exact test or Fisher's Exact test using IBM SPSS Statistics, version 29. Significance level to determine statistical difference was set at $p < 0.05$. This QI report was prepared in keeping with the Standards for Quality Improvement Reporting Excellence (SQUIRE) guidelines.[12]

RESULTS

A total of 34 participants completed both the pre- and post-education surveys. The study cohort consisted of 16 orthopaedic surgery residents and 18 other trauma staff members, with nine participants from each trauma center. Pre- and post-survey comparisons are presented in Table 1.

Before the intervention, most respondents (68%, 23/34) strongly agreed or agreed that they experienced confusion when administering prophylactic antibiotics for open fractures. Awareness of an existing antibiotic prophylaxis protocol increased significantly from 29% (10/34) in the pre-survey to 100% (34/34) in the post-survey ($p < 0.001$). Agreement that an antibiotic prophylaxis algorithm would be very helpful also increased, from 53% (18/34) before the intervention to 82% (28/34) afterward ($p = 0.023$).

Participant comfort levels in managing open fractures improved markedly following implementation of the protocol. Those who reported feeling *very comfortable* increased from 9% to 71% ($p < 0.001$) for type 1 or 2 fractures and from 6% to 68% ($p < 0.001$) for type 3 fractures. While comfort levels improved among both orthopaedic residents and other trauma staff, the increase was greater in the orthopaedic resident cohort (Figure 2).

Knowledge assessment results are summarized in Table 1. Overall, the average increase in correctly identifying the preferred antibiotic regimen across all clinical scenarios was 49%, with post-survey accuracy ranging from 68% to 100%. The largest improvement was observed in the type 3 open fracture scenario involving a gunshot wound with perforated bowel and pelvic involvement, where correct identification of piperacillin/tazobactam increased from 15% to 82% ($p < 0.001$). Participants correctly identifying the preferred regimen in all three type 3 open fracture scenarios increased by an average of 58%, with all improvements reaching statistical significance ($p < 0.001$).

Knowledge improvement in the type 1 open fracture scenario was not statistically significant, as most participants (88%) had already correctly identified cefazolin as the antibiotic of choice in the pre-survey.

No clinical outcome measures, such as time to antibiotic administration or patient infection rates, were assessed in this study.

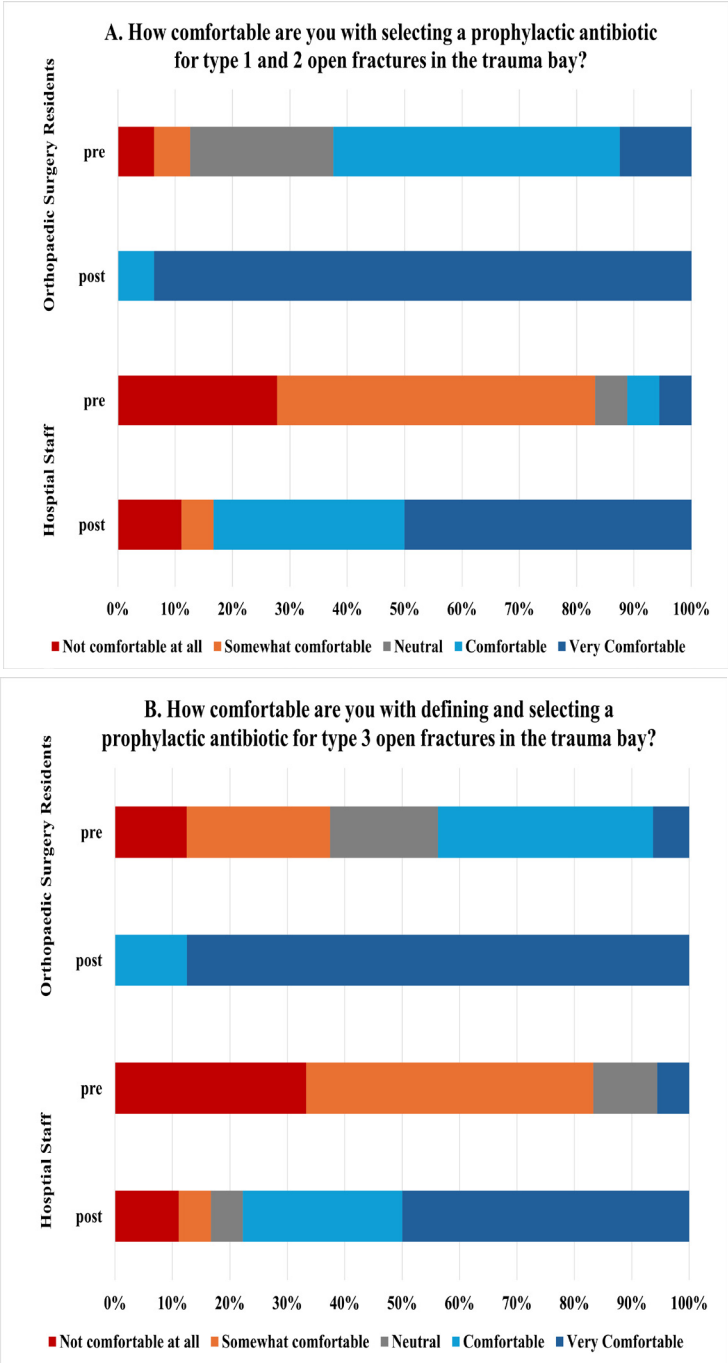

Figure 2. Changes in pre- and post-education comfort level among orthopaedic surgery residents and hospital trauma staff selecting prophylactic antibiotics for (A) type 1 and 2 and (B) type 3 open fractures.

DISCUSSION

The present QI initiative significantly improved participants' awareness of the antibiotic protocol for open fracture management and increased their comfort level in selecting prophylactic antibiotics. Knowledge of the correct antibiotic for specific open fracture clinical scenarios also improved. The simplified antibiotic regimen and educational posters displayed in the emergency departments showed to be an effective strategy for enhancing open fracture care at the regional Level 1 trauma centers.

While participants demonstrated competence in selecting prophylactic antibiotics for type 1 open fractures, pre-intervention survey results revealed deficiencies in knowledge regarding higher-grade open fractures. These findings align with those of Lin et al.,[13] who reported moderate adherence to antibiotic prophylaxis guidelines for Gustilo type 1 and 2 open fractures, but low adherence for type 3 injuries. This knowledge gap among trauma personnel may contribute to delays or omissions in selecting the recommended prophylactic antibiotic regimen for severe open fractures.

Prompt administration of antibiotics in open fracture management is a well-established measure for reducing postoperative SSIs. For instance, Siebler et al.[8] reported a significant reduction in time to antibiotic administration following implementation of a standardized protocol. Although the present study did not evaluate time to antibiotic administration or other patient outcome data, the observed improvements in knowledge and comfort with open fracture management suggest that similar QI strategies could yield clinical benefits.This study is limited by its small sample size, which makes it statistically underpowered, its single geographic region setting, and the absence of clinical outcome measures due to its focus on participant knowledge and confidence in antibiotic prophylaxis. Additionally, participant bias may have influenced the study results.

CONCLUSIONS

This QI initiative significantly increased subjective comfort with and objective knowledge of prophylactic antibiotic management for type 3 open fractures among trauma staff members at two Level 1 trauma centers. Future efforts to assess time to antibiotic administration and post-operative infection rates at both trauma centers may be helpful to evaluate the clinical impact of this QI intervention.

Table 1. Unmatched comparison of pre- and post-education anonymous survey responses.

Question	Response	Pre-survey	Post-survey		
		n (%)	n (%)	$\chi 2$ (*df*)	*P* value
Respondent	Orthopaedic resident	16 (47.1)	16 (47.1)	0.0 (2)	>.999
	Other trauma staff (hospital #1)	9 (26.5)	9 (26.5)		
	Other trauma staff (hospital #2)	9 (26.5)	9 (26.5)		
Have you experienced confusion regarding antibiotic prophylaxis for open fracture management in the trauma bay which ultimately delayed time to antibiotic administration	Strongly disagree	2 (5.9)			
	Disagree	3 (8.8)			
	Neutral	6 (17.6)			
	Agree	10 (29.4)			
	Strongly agree	13 (38.2)			
Are you aware of a protocol for antibiotic prophylaxis for open fracture management in the trauma bay?	Yes	10 (29.4)	34 (100.0)	37.1 (1)	<.001*
	No	24 (70.6)	0 (0)		
How helpful would an antibiotic prophylaxis algorithm be for open fracture management in the trauma bay?	Not helpful at all	0 (0)	0 (0)	7.4 (3)	0.023
	Somewhat helpful	1 (2.9)	0 (0)		
	Neutral	1 (2.9)	0 (0)		
	Helpful	14 (41.2)	6 (17.6)		
	Very helpful	18 (52.9)	28 (82.4)		
Comfort Level					
How comfortable are you with selecting a prophylactic antibiotic for type 1 and 2 open fractures in the trauma bay?	Not comfortable at all	6 (17.6)	2 (5.9)	31.9 (4)	<.0001
	Somewhat comfortable	11 (32.4)	1 (2.9)		
	Neutral	5 (14.7)	0 (0)		
	Comfortable	9 (26.5)	7 (20.6)		
	Very Comfortable	3 (8.8)	24 (70.6)		
How comfortable are you with defining and selecting a prophylactic antibiotic for type 3 open fractures in the trauma bay?	Not comfortable at all	8 (23.5)	2 (5.9)	34.3 (4)	<0.001
	Somewhat comfortable	13 (38.2)	1 (2.9)		
	Neutral	5 (14.7)	1 (2.9)		
	Comfortable	6 (17.6)	7 (20.6)		
	Very Comfortable	2 (5.9)	23 (67.6)		
Knowledge Assessment					
A patient presents with a trimalleolar ankle fracture with a 1 cm open laceration over the fracture site. What antibiotic prophylaxis should be administered?	**Cefazolin**	30 (88.2)	34 (100.0)	4.3 (2)	0.114
	Ceftriaxone	0 (0)	0 (0)		
	Piperacillin/Tazobactam	2 (5.9)	0 (0)		
	Cefazolin + Gentamicin	2 (5.9)	0 (0)		
A patient presents with a segmental tibia fracture and 2 cm laceration over the fracture site. What antibiotic prophylaxis should be administered?	**Piperacillin/Tazobactam**	3 (8.8)	23 (67.6)	28.5 (3)	<0.001
	Cefazolin	21 (61.8)	11 (32.4)		
	Cefazolin + Gentamicin	7 (20.6)	0 (0)		
	Ceftriaxone	3 (8.8)	0 (0)		
Which antibiotic has non-inferior rates of surgical site infections when compared to cefazolin + gentamicin when being used for clean type 3 open fractures?	**Ceftriaxone**	15 (44.1)	32 (94.1)	20.2 (3)	<0.0001
	Ancef	13 (38.2)	2 (5.9)		
	Amoxicillin	1 (2.9)	0 (0)		
	Cefuroxime	5 (14.7)	0 (0)		

Note: Fisher-Freeman-Halton Exact test, unless otherwise specified. *Fisher's Exact test.
Correct responses to the knowledge assessment items are shown in bold.
Overall average increase, pre- to post-intervention, for correct responses was 48.8%.

Table 1. Unmatched comparison of pre- and post-education anonymous survey responses. *Continued*

		Pre-survey	Post-survey		
Question	**Response**	**n (%)**	**n (%)**	*χ2 (df)*	***P* value**
What antibiotic has non-inferior rates of surgical site infections when compared to cefazolin + gentamicin + penicillin when being used for grossly contaminated type 3 open fractures in the setting of farm injury or standing water?	Penicillin + Doxycycline	3 (8.8)	0 (0)	24.2 (4)	<0.001
	Ceftriaxone	7 (20.6)	1 (2.9)		
	Cefepime	7 (20.6)	0 (0)		
	Piperacillin/Tazobactam	12 (35.3)	31 (91.2)		
	Cefazolin + Piperacillin/Tazobactam	5 (14.7)	2 (5.9)		
What antibiotic should be administered for a gunshot wound with perforated bowel and bony pelvic involvement?	Cefazolin + gentamycin	4 (11.8)	0 (0)	32.0 (3)	<0.001
	Metronidazole + penicillin	8 (23.5)	1 (2.9)		
	Piperacillin/Tazobactam	5 (14.7)	28 (82.4)		
	Ceftriaxone + Metronidazole	17 (50.0)	5 (14.7)		

Note: Correct responses to the knowledge assessment items are shown in bold.
Overall average increase, pre- to post-intervention, for correct responses was 48.8%.

ARTICLE INFORMATION

Received July 16, 2025; Accepted for publication November 3, 2025; Published online Dec. 16, 2025, Kans J Med 2025 Nov-Dec; 18:134-138. https://doi.org/10.17161/kjm.vol18.24171.

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Keywords: *antibiotic prophylaxis, continuing medical education, open fracture, quality improvement*