Adherence to perioperative antibiotic prophylaxis among orthopedic trauma patients

Kristopher M. Lundine, MD MSc*
Susan Nelson, BSc BPHE†
Richard Buckley, MD*
Sven Putnis, MBChB‡
Paul J. Duffy, MD*

From the *Division of Orthopaedics, Health Sciences Centre, Calgary, Alta., the †School of Medicine, Queen's University, Kingston, Ont., and the ‡Trauma & Orthopaedic Registrar, St. Georges Hospital, London, United Kingdom

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Correspondence to:
Dr. K.M. Lundine
Division of Orthopaedics
Health Sciences Centre
3330 Hospital Dr. NW
Calgary AB T2N 4N1
krislundine@hotmail.com

Background: The goal of this study was to assess whether patients receive their antibiotic prophylaxis as prescribed. We also investigated what doses and durations of antibiotics are typically ordered, which patients actually receive antibiotics and factors causing the ordered antibiotic regimen to be altered.

Methods: We performed a retrospective review of 205 patient charts and sent a national survey to all surgeon members of the Canadian Orthopaedic Trauma Society (COTS) about antibiotic prophylaxis in the setting of surgical treatment for closed fractures.

Results: In all, 93% (179 of 193) of patients received an appropriate preoperative dose of antibiotics, whereas less than 32% (58 of 181) of patients received their postoperative antibiotics as ordered. The most commonly stated reason for patients not receiving their postoperative antibiotics as ordered was patients being discharged before completing 3 postoperative doses. There was a 70% (39 of 56) response rate to the survey sent to COTS surgeons. A single dose of a first-generation cephalosporin preoperatively followed by 3 doses postoperatively is the most common practice among orthopedic trauma surgeons across Canada, but several surgeons give only preoperative prophylaxis.

Conclusion: Adherence to multidose postoperative antibiotic regimens is poor. Meta-analyses have failed to demonstrate the superiority of multidose regimens over single-dose prophylaxis. Single-dose preoperative antibiotic prophylaxis may be a reasonable choice for most orthopedic trauma patients with closed fractures.

Contexte : Cette étude visait à déterminer si les patients reçoivent la prophylaxie aux antibiotiques prescrite. Nous avons aussi étudié les doses prescrites habituellement et leur durée, quels patients reçoivent effectivement des antibiotiques et les facteurs à cause desquels le régime antibiotique prescrit est modifié.

Méthodes : Nous avons procédé à une étude rétrospective de 205 dossiers de patients et envoyé un questionnaire national à tous les chirurgiens membres de la Société canadienne de traumatologie orthopédique (SCTO) au sujet de la prophylaxie aux antibiotiques en contexte de traitement chirurgical de fractures fermées.

Résultats : Au total, 93 % (179 sur 193) des patients ont reçu la dose préopératoire appropriée d'antibiotiques, tandis que moins de 32 % (58 sur 181) des patients ont reçu les antibiotiques prescrits après l'intervention. La raison mentionnée le plus souvent pour justifier l'omission des antibiotiques prescrits après l'intervention, c'est que les patients reçoivent leur congé avant d'avoir pris 3 doses postopératoires. Le taux de réponse au questionnaire envoyé aux chirurgiens membres de la SCTO a atteint 70 % (39 sur 56). Une seule dose d'une céphalosporine de première génération administrée avant l'intervention et 3 doses administrées après l'intervention constituent la pratique la plus courante chez les chirurgiens en traumatologie orthopédique au Canada, mais plusieurs chirurgiens administrent seulement une prophylaxie préopératoire.

Conclusion : Les protocoles antibiotiques postopératoires à doses multiples sont peu observés. Les méta-analyses n'ont pas démontré la supériorité des protocoles à doses multiples sur la prophylaxie à une seule dose. La prophylaxie aux antibiotiques préopératoire à une seule dose peut constituer un choix raisonnable pour la plupart des patients en traumatologie orthopédique qui ont une fracture fermée.

The rate of infection following surgical treatment of closed fractures is low, with reported rates of 0.5%–5%.[1] However, the potential for complications associated with infection of surgical implants substantiates the need for antibiotic prophylaxis.[2,3] The use of antibiotic prophylaxis in the setting of clean surgery is well established in the literature.[2–10] It has been found to

significantly decrease surgical site infections and other nosocomial postoperative infections such as urinary and respiratory tract infections.[4,5,11–13]

Although the practice of providing antibiotic prophylaxis is well accepted, the duration of prophylaxis remains controversial. Current guidelines suggest that intravenous (IV) antibiotic prophylaxis be given within 30–60 minutes before the first surgical incision.[2,3,5,8–10,14,15] Some evidence supports the trend toward shorter antibiotic durations lasting no more than 24 hours after surgery for closed fractures.[16–18]

The goal of antibiotic prophylaxis in surgery is to achieve serum and tissue drug levels that exceed the minimum inhibitory concentration for organisms likely to be encountered during surgery for the duration of the operation.[14] Current best evidence from the literature, based on data from meta-analyses[12,13] and a recent Cochrane review,[11] have not shown a difference between single-dose preoperative antibiotic prophylaxis and multiple-dose prophylaxis.

Despite recommendations, some patients may receive inadequate antibiotic prophylaxis. Results from both the National Surgical Infection Prevention Project in the United States[19] and a Canadian study involving patients with hip fractures[20] revealed that only 55.7% and 30% of patients, respectively, received an effective first dose of prophylactic antibiotics. A recent chart review from the United Kingdom found that 76% of patients with hip fractures received antibiotics outside the prescribed dosing interval,[21] and another unpublished review found that less than 50% of patients receive antibiotic prophylaxis as outlined by local guidelines.[22]

First-generation cephalosporins are commonly prescribed for prophylaxis, but concerns exist for patients with an allergy to penicillin. In this situation, it is not uncommon for an alternative antibiotic to be prescribed for surgical prophylaxis because of concerns about cross-reactivity.[23] Recent literature, however, suggests that true penicillin allergies may be much less common than actually reported by patients[23] and that the true cross-reactivity to cephalosporins may be less than 5%.[24,25]

Given the evidence of poor adherence to antibiotic prophylaxis regimens, our primary goal was to determine what proportion of patients undergoing surgery for a closed fracture received their antibiotic prophylaxis as prescribed. We also explored the national practice patterns of orthopedic trauma surgeons concerning antibiotic prophylaxis and reviewed the current literature on the topic. We did not design this study to compare infection rates between patients who received a full course of postoperative antibiotic prophylaxis and those who did not.

Methods

The study population consisted of consecutive patients who received surgery for a closed fracture by 1 of 2 trauma surgeons at a single tertiary care trauma centre between May and December 2007. We selected patients from a database of surgically managed patients at our institution. We included those who had closed fractures requiring surgical treatment and who were 16 years or older. We excluded patients with open fractures; those who were receiving antibiotics for reasons other than surgical prophylaxis; those scheduled for day surgery, total-joint arthroplasty or spine surgery; and those whose charts were unavailable for review.

In this retrospective chart review, we examined the charts of 205 patients for pre- and postoperative antibiotic orders and what pre- and postoperative antibiotics each patient received. The data collected included type and dosage of antibiotic, the number of doses and time between doses. Any deviation from the ordered regimen, along with any reasons for the deviation, were also noted. Correct timing of antibiotic dosing was defined as within 1 hour of the ordered schedule, as per local nursing guidelines. This could be tracked by use of local electronic health records. We also collected demographic information and operative and fracture details.

To assess national surgeon preferences and trends in antibiotic prophylaxis prescription, we created a survey using an online survey tool. The survey was emailed to all surgeon members (n = 56) of the Canadian Orthopaedic Trauma Society (COTS) in July 2008. Surgeons were contacted again in September 2008 to help optimize the response rate. The survey included a total of 4 questions about prescribing patterns for typical pre- and postoperative prophylaxis in patients undergoing surgery for closed fractures; scenarios included both standard adult patients and adult patients with a reported penicillin allergy). The questions were multiple choice with options including nothing, cefazolin, ceftriaxone, clindamycin, vancomycin or other. Surgeons who selected "other" were asked to elaborate on their responses.

We analyzed all data for descriptive statistics using SPSS software.

This research received ethical approval from the academic review board of the local institution.

Results

In all, we reviewed 205 patient charts. Three patients had 2 surgeries for separate closed fractures, therefore, we included 208 cases for analysis.

Patient demographic information is outlined in Table 1. Nonanaphylactic allergies to penicillin were reported by patients in 8% (16 of 208) of cases. One patient reported a history of anaphylaxis to cephalosporins. Nine of these patients received pre- and postoperative orders for cefazolin, 5 received pre- and postoperative orders for clindamycin, 1 a combination of preoperative clindamycin and postoperative cefazolin, and 1 a combination of preoperative cefazolin and postoperative vancomycin. All pre- and postoperative orders for clindamycin or vancomycin were for patients with reported penicillin or cephalexin allergies.

All patients not reporting an allergy to antibiotics received an order for preoperative cefazolin followed by 3 postoperative doses of cefazolin given over 24 hours. One patient, who reported a nonanaphylactic penicillin allergy, was given cefazolin prophylaxis and experienced an allergic event, which was nonanaphylactic. All patients had 24 hours of postoperative antibiotics ordered.

Table 2 outlines the data collected concerning the primary focus of this study. Considering all factors pre- and postoperatively, 32% (58 of 181) received their entire antibiotic prophylaxis regimen correctly. The data concerning patients who received any pre- or postoperative dosing, correct number of dosages and correct timing of dosages are also presented. Data regarding the number of doses or the timing of doses were not recorded in 27 of the patient charts. We excluded patients with incomplete data from analysis within the respective data sets.

Table 1. Demographic characteristics of patients who had surgery for closed fractures

Characteristic	No. (%)*
Age, mean (range) yr	53.6 (16–99)
Sex	
Male	114 (54.8)
Female	94 (45.2)
Fracture location†	
Clavicle	5 (2.4)
Humerus	11 (5.3)
Elbow	11 (5.3)
Radius/ulna	21 (10.1)
Carpal	3 (1.4)
Hip	69 (33.2)
Femur	13 (6.3)
Patella	4 (1.9)
Tibia/fibula	32 (15.4)
Ankle	24 (11.5)
Foot	19 (9.1)
Antibiotic allergy reported	
Penicillin	16 (7.7)
Cephalexin	1 (0.5)
Sulpha drugs	7 (3.4)

*Unless otherwise indicated.
†Some patients had more than 1 fracture; thus, the total number of fractures is > 208 and the percentiles total > 100%.

Reasons for not receiving antibiotics as prescribed are outlined in Table 3. Overall, 62% (76 of 123) of charts contained no reason for a missed dose or dose not given on time. The most common reason for a missed dose was that the patient was discharged before all ordered doses had been given. Two patients had more than 1 reason stated in their charts.

Results from the survey distributed to COTS surgeons are outlined in Table 4. Thirty-nine of 56 surgeons responded for a response rate of 70%. All respondents chose cefazolin as their preoperative antibiotic of choice for patients who were not allergic to penicillin. The 4 surgeons who chose "other" as an item response commented that the dose depended on the weight of the patient, with heavier patients receiving 2 g administered intravenously. One surgeon reported routinely prescribing 2 g administered intravenously. Postoperatively, 2 surgeons chose "other" noting that the number of postoperative doses they prescribe decreases if it is felt that the patient would be discharged earlier than 24 hours postoperatively.

In the scenarios with patients allergic to penicillin, 5 surgeons either selected "other" or commented that their antibiotic choice depended on the severity of the reported allergy. No surgeon selected clindamycin or vancomycin as their first-line therapy if the patient didn't report an allergy. None of the surgeons selected ceftriaxone in any of the scenarios; thus, this option is not displayed in Table 4.

Discussion

This study demonstrates that about three-quarters of patients received their postoperative antibiotic prophylaxis, but only one-third of patients received them as ordered. This result is similar to reports from other institutions.[21,22] This begs the question: Is postoperative prophylaxis necessary? The current best evidence in the medical literature has been unable to demonstrate additional benefit with postoperative antibiotics over isolated preoperative prophylaxis. Fewer doses carry the benefits of reducing duration and cost of health care, with fewer consequences for the microbial flora of the patient or institution.[2,9,11–13]

A recent meta-analysis of 10 papers including 2417 patients with hip fractures showed a significant risk reduction of wound infection with preoperative prophylactic antibiotics; however, additional postoperative doses presented

Table 2. Descriptive statistics of antibiotic prophylaxis received*

Time of administration	Antibiotics received; no. (%)			
	Any no. doses and time	Correct no. doses	Correct time†	Correct no. doses and time†
Before surgery	199/208 (96)	199/208 (96)	179/193 (93)	179/193 (93)
After surgery	187/208 (90)	149/189 (79)	80/184 (43)	62/181 (34)
Before and after surgery	183/208 (90)	146/189 (77)	75/184 (41)	58/181 (32)

*We excluded any chart not containing the requisite data from analysis for each individual data set.
†We defined correct time as ± 1 hour as per regional nursing protocol.

no further reduction in risk over a single dose at induction of anesthesia.[13] Another meta-analysis of antibiotic prophylaxis for treatment of closed long bone fractures including 3808 patients failed to show lower rates of surgical site infection with multiple-dose regimens compared with single-dose regimens.[12] However, those authors could not definitively recommend a prophylactic regimen owing to wide confidence intervals around the pooled risk ratio. More specifically, a Cochrane review addressing antibiotic prophylaxis for treatment of closed long bone fractures[11] considers long- versus short-acting antibiotics. The authors conclude that antibiotics with half lives long enough to maintain minimum inhibitory concentrations over 12 hours can be given as a single dose, which is as effective as multiple, short-acting doses. It has been shown that as many as 20% of surgical patients receiving appropriately timed preoperative cefazolin will have an end of procedure–free serum cefazolin level below the minimum inhibitory concentration (4 µg/mL) for methicillin-susceptible *Staphylococcus aureus* (MRSA) and *Escherichia coli*.[26]

Table 3. Reasons why antibiotic prophylaxis was not received correctly (*n* = 123)

Reason*	No. (%)
No reason documented	76 (62.0)
Patient discharged	19 (15.0)
Antibiotics unavailable	8 (6.5)
Order discontinued	7 (5.7)
Patient away for other procedure	4 (3.3)
Duplicate order	3 (2.4)
Patient off ward	2 (1.6)
Intravenous line out	2 (1.6)
Preoperative dose counted as first postoperative dose	2 (1.6)
Wrong chart	1 (0.8)
Medication conflict	1 (0.8)

*Some patients had more than 1 reason stated in the chart.

All of the COTS survey respondents prescribe preoperative prophylactic antibiotics but 15% do not routinely prescribe postoperative prophylaxis. This may demonstrate a changing trend toward of the utility of single-dose prophylaxis in the surgical treatment of closed fractures.

Methods for improving compliance with prescription of antibiotics have been suggested, including electronic distribution of guidelines,[27,28] preprinted chart stickers[29] and closer collaboration with pharmacy.[30] Information about improving administration has focused largely on the preoperative period.[31–33] The use of a surgical "time out" in the operating room before incision has been shown to increase administration of preoperative antibiotics.[34]

Our institution uses a preoperative time-out period in the operating room, and 93% of patients in our study received preoperative prophylaxis appropriately. Still, this means that about 1 of 13 patients did not receive appropriate preoperative prophylaxis. Nine patients had no documented dose of preoperative antibiotics, and 15 patients had no documentation regarding the timing of their preoperative doses. In 5 cases, the preoperative dose was given after the initial skin incision. This may be a reflection of inadequate documentation rather than true medical error. Nevertheless, this data demonstrates an opportunity for substantial improvement in overall patient care. We did not address the issue of optimal timing of preoperative antibiotics in this study, but it is an important topic deserving further research in the orthopedic trauma population.

The electronic health record used for tracking orders and nursing care at our institution was extremely helpful for data collection. Despite this electronic system, only 1 of 3 patients in our study received their postoperative prophylaxis as ordered. Postoperatively, the administration of antibiotics most often involves nursing care. A national medication error reporting study from the *Journal of Infusion Nursing* found over a 5-year period that commonly reported IV-related medication errors in the United States included omissions (28.5%), improper dosing (22.9%) and

Table 4. Descriptive statistics of survey responses by COTS surgeons (*n* = 39)

Timing of administration; dosage; survey item	Antibiotic; no. (%) responses*				
	Cefazolin	Clindamycin	Vancomycin	Nothing	Other
Preoperative					
Dosage	1 g IV	600 mg IV	1 g IV		
Standard patient	35 (90)	0	0	0	4 (10)
Patient with penicillin allergy	1 (3)	30 (77)	6 (15)	0	2 (5)
Postoperative					
Dosage	1 g IV every 8 h x 3 doses	600 mg IV every 8 h x 3 doses	1 g IV every 12 h x 2 doses		
Standard patient	31 (80)	0	0	6 (15)	2 (5)
Patient with penicillin allergy	2 (5)	21 (54)	7 (18)	6 (15)	3 (8)

COTS = Canadian Orthopaedic Trauma Society; IV = intravenous.
*Unless when reporting dosage.

prescription errors (16.2%). The most common reported reasons for errors involved a clinical performance deficit. These deficits included failing to perform the task (48%), not following procedure or protocol (28%) and inaccurate or omitted transcription (14%).[35]

In the present study, dose omissions were not as much of an issue as improper dosing, especially with timing of postoperative doses. Nursing guidelines at our institution gave an acceptable timeframe for dose administration as ± 1 hour of the scheduled time. In all, 79% of patients received postoperative antibiotics. However, only 34% received those doses correctly; 61% of patients had no documented reasons for receiving an incorrect antibiotic prophylaxis regimen. This presents another opportunity to improve the tracking and documenting of patient care.

Investigating factors influencing nursing staff performance may help bring about strategies for improving adherence to medication administration. For antibiotic prophylaxis, each additional postoperative dose creates additional work and thus an opportunity for error. Single-dose preoperative prophylactic regimens would eliminate the problems with postoperative prophylactic antibiotic administration entirely. This could help reduce the workload of the nursing staff, simplifying the postoperative management of patients and potentially decrease the overall incidence of medical errors.

Of patients with reasons for not receiving appropriate antibiotics, 20 (16.1%) were related to logistics of the ward or hospital (patient discharged, antibiotics unavailable, patient off the ward, patient undergoing another procedure). Eleven (8.9%) patients had a failure related to prescription (discontinued order, medication conflict, duplicate order), whereas only 4 (3.2%) patients had failures relating to human error (wrong chart, preoperative dose counted as first postoperative dose). In the chart review, it was also noted that some of the errors were due to miscommunication that the timing of the first postoperative dose should be 8 hours after the preoperative dose. Several of the COTS surgeons mentioned that they would regularly decrease the postoperative dosing schedule if they felt the patient would be ready for discharge before 24 hours. The potential exists to facilitate discharge if patients are being kept in hospital simply to receive 3 postoperative doses of IV antibiotics.

Reducing the duration of antibiotic prophylaxis has many potential benefits. In addition to simplifying postoperative nursing care, reducing antibiotic doses presents a potential for cost savings to the health care system. Longer duration of antibiotic prophylaxis has also been associated with emerging microbial antibiotic resistence.[36,37] Decreasing duration of prophylaxis has been shown to reduce MRSA isolation levels on an orthopedic ward.[17]

Patients with 1 drug allergy may have an increased risk of reaction to other antibiotics. In a review combining data from 11 studies, the rate of allergic reactions to cephalosporins was 4.4% in the patient population with a confirmed penicillin allergy (skin testing) as compared with 0.6% in the population not allergic to penicillin.[38] Many patients who report a penicillin allergy are not truly allergic as demonstrated by studies using skin testing.[23] The rate of anaphylaxis following cephalosporin administration in a population allergic to penicillin has been reported to be as low as 0.001%.[39]

Sixteen patients in our study reported an allergy to penicillin but only 1 of those was reported as anaphylaxis. In the data from the COTS survey, there exists no clear consensus regarding antibiotic prophylaxis in patients reporting a penicillin allergy. Currently, there is evidence to support the safe use of cephalosporins in patients with reported penicillin allergies if the allergy is not reported as anaphylaxis.[39–42]

Limitations

This study contains several limitations. First, the chart review represents patients of only 2 surgeons. However, the prescribing patterns of these 2 surgeons are consistent with the data collected from other surgeons across the country. Second, this study was performed at a single institution, but the data collected was consistent with previous reports from other academic tertiary care trauma centres.[21,22] A retrospective study contains inherent bias, but we felt that performing a prospective study could potentially introduce a "Hawthorne effect"[43] and thereby alter the variables under investigation. The response rate from the COTS survey was 70%, introducing the potential for respondent bias.

The optimal antibiotic prophylaxis regimen in the setting of clean surgical treatment of closed fractures is controversial. Current best evidence suggests that postoperative antibiotics do not significantly improve outcomes or infection rates over a single preoperative dose given 30–60 minutes before skin incision. In this study, 93% of patients received an appropriate preoperative dose, whereas only 34% of patients received their postoperative antibiotics as ordered. Among COTS surgeons, a single dose of a first-generation cephalosporin preoperatively followed by 3 doses postoperatively is the most common antibiotic prophylaxis ordered, but 15% of surgeons use only the preoperative dose. Clindamycin is the most common antibiotic ordered for patients with reported penicillin allergies.

CONCLUSION

Pooled meta-analyses have failed to demonstrate the superiority of multi-dose antibiotic prophylaxis regimens over a single preoperative dose in the surgical treatment of closed fractures. This study demonstrates that adherence to multiple-dose regimens is poor. Single-dose regimens may be appropriate in most settings of closed orthopaedic trauma.

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