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Original Research

Antibiotic Prophylaxis in the Management of Distal Fingertip Amputation and Crush Injury

Eliana Schaefer, MD, MS, [*,†] Jonathan Lawson, MS, [*,†] Tamara Ibrahim, BS, [*,†] Gabriel Yohe, MS, [*,‡] Gongliang Zhang, PhD, MS, [*,‡] Aviram M. Giladi, MD, MS [*]

[*] The Curtis National Hand Center, MedStar Union Memorial Hospital, Baltimore, MD
[†] Georgetown University School of Medicine, Washington, DC
[‡] MedStar Health Research Institute, Hyattsville, MD

A R T I C L E I N F O

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Purpose: We sought to investigate the role of prophylactic antibiotics for distal fingertip crush injury or transphalangeal amputation treated outside of an operating room and better understand the factors that contribute to antibiotic-prescribing decisions. We hypothesized that prophylactic antibiotics do not meaningfully reduce the incidence of infection and that antibiotics are prescribed in a predictable way.
Methods: This is a retrospective review of all patients treated in a MedStar-affiliated emergency department or urgent care for nonsurgical distal fingertip trauma in 2019. Patient demographics, comorbidities, injury characteristics, interventions, and follow-up details were recorded. Exclusion criteria included signs of infection at the time of presentation, minor injuries not requiring intervention, bite wounds, one-time intravenous antibiotic administration without oral course, and surgical intervention. Outcomes included infection and interventions at follow-up. Chi-square analysis was performed, comparing antibiotic and no-antibiotic groups. A stepwise binomial regression was used to evaluate for variables predictive of antibiotic prescription.
Results: We identified eight infections in 323 patients included in the study (2.5% incidence of infection). There was no statistically significant difference in the incidence of infection between patients treated with antibiotics (2.7%) and those who did not receive antibiotics (2.2%). However, due to the low incidence of infections, we were likely underpowered for this analysis. We also created a model to predict antibiotic prescribing, which achieved an area under the receiver operating characteristic curve of 0.86 ($P < .0001$) based on age, bleeding disorders, depressive disorders, open wound status, amputation, fractures, and encounter type.
Conclusions: The low incidence of infection (2.5%) and lack of a meaningful difference between the groups call into question prophylactic antibiotic prescribing after these distal fingertip injuries. Our model does predict provider prescribing habits, identifying areas for potential practice pattern change.
Type of study/level of evidence: Therapeutic III.

The United States averages more than 8.6 million emergency department (ED) visits annually for hand-related conditions, the majority of which are for traumatic open injuries.[1] However, the use of prophylactic antibiotics for various hand injuries remains controversial. Although prophylactic antibiotic treatment is part of routine care for other open injuries (eg, open fractures of long bones), there are no definitive guidelines for this practice in the setting of hand trauma.[2] Unlike open fractures of long bones, some open fractures of the hand can be treated definitively in the ED.[3] The decision to prescribe antibiotics for most traumatic hand injuries remains up to provider discretion or preference. Several studies and meta-analyses have demonstrated that prophylactic antibiotics do not reduce the infection incidence after hand

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Corresponding author: Aviram M. Giladi, MD, MS, the Curtis National Hand Center, MedStar Union Memorial Hospital, 3333 N. Calvert St., JPB Mezzanine, Baltimore, MD 21218.

E-mail address: editor@curtishand.com (A.M. Giladi).

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lacerations; however, they are often still prescribed.[4−7] There is also evidence to suggest that this holds true for more complex injuries, such as distal fingertip fractures and amputations.[8,9]

If prophylactic antibiotics do not meaningfully reduce infection risk for these injuries, changes to clinical practice guidelines might have far-reaching implications. Antibiotic stewardship is a major focus of many institutions, as antimicrobial resistance (AMR) persists as a growing public health risk.[10−12] Sartelli et al[12] underscored this sentiment in their worldwide cross-sectional study, concluding that awareness of the global burden of AMR among health care workers was considered very important or important by 54.6% of the participants. The risks of AMR to patient health and the global challenge to avoid further AMR development require rigorous investigation to ensure accurate and effective use of antibiotics.

Prior studies evaluating the effectiveness of prophylactic antibiotic use for various complex hand injuries are limited to small randomized controlled trials (RCTs). However, these types of hand injuries generally have an extremely low incidence of infection, so associating infection with lack of antibiotic use is difficult to demonstrate.[8,13,14] Additionally, these studies excluded comorbid patients or those considered "high risk" for development of infection based on comorbities.[8,13,14] We sought to investigate this topic in a generalized setting, including all patients, regardless of immunologic status. This study aims to further describe whether there is a role for prophylactic antibiotics in the management of certain hand injuries as well as to identify trends in provider prescribing habits. We hypothesized that prophylactic antibiotics will not meaningfully reduce infection incidence after distal fingertip amputation or crush injuries that are not extensive enough to require treatment in an operating room. We aim to contribute to the body of evidence that determines the necessity of antibiotic prophylaxis in this setting and catalyze a shift toward standardization of prescribing protocols.

Methods

This is a retrospective cohort study using data from the MedStar Health Electronic Health Records and associated Health Information Exchange. Institutional Review Board of MedStar Health Research Institute approval was obtained. The cohort consists of patients treated in a MedStar-affiliated ED or urgent care facility for distal fingertip crush injury or transphalangeal amputation from January 1, 2019, to December 31, 2019. We defined moderate severity trauma as injuries that involved a fracture and/or an open wound that required urgent/emergent care but were not taken to the operating room.

We sought to focus on distal fingertip fractures and amputations; however, we included a variety of traumatic injuries to compare across different injuries. Patients were identified on the basis of International Classification of Diseases, 10th Revision, codes for diagnosis and/or mechanism of injury (Appendix A, available online on the Journal's website at https://www.jhsgo.org). The MedStar electronic medical records, Greater Chesapeake Hand to Shoulder (outside private practice affiliated with our hand center) electronic medical records, and Chesapeake Regional Information System for our Patients, Maryland's state-designed Health Information Exchange, were reviewed for patient demographics, comorbidities, injury characteristics, aspects of wound severity, interventions, injury management, and follow-up details.

Patient demographics included age, sex, and body mass index. Comorbidities included tobacco use, alcohol use disorder, bleeding disorder, chronic obstructive pulmonary disease, depression, diabetes, HIV/AIDS, heart failure, hyperlipidemia, hypertension, immunodeficiency, ischemic heart disease, leukemias and lymphomas, malnutrition, nutritional deficiencies, nutritional anemias, obesity, peripheral vascular disease, asplenia, chronic kidney disease, chronic liver disease, lymphocytopenia, and neutropenia. Immunocompromising diagnoses were grouped for analysis purposes, and immunosuppressive medications were recorded (Appendix B, available online on the Journal's website at https://www.jhsgo.org). Injury characteristics included injury type (crush or amputation), hand injured, location on hand, injury environment, mechanism of injury, nail bed injury, joint injury, nerve injury, vascular injury, ligament injury, amputation site, and presence of a fracture (site, intra-articular vs extra-articular, and open vs closed). Interventions included treatment location (ED vs prompt care vs operating room), intravenous antibiotic use (type, dose, duration, and prescriber), and oral antibiotic use (type, dose, duration, and prescriber). Follow-up details included time since initial presentation; signs of infection; infectious International Classification of Diseases, 10th Revision, code; and interventions; including debridement, incision and drainage, surgical treatment, or a new antibiotic prescription. Patients without fractures or open wounds were excluded, as were those with signs of infection at presentation, bite wounds, intravenous antibiotic administration without oral antibiotic course, prisoners who received treatment, and surgical intervention in an operating room. Patients with multiple hand injuries, one of which was an amputation, were categorized in the amputation cohort. Infectious outcome was defined by a new diagnosis of infection or the presence of specific interventions related to infection including debridement, incision and drainage, or a new antibiotic prescription at follow-up.

Chi-square analysis was performed to evaluate for differences in the incidence of infection. More advanced analyses were initially considered; however, the low overall incidence of infection reduced the likelihood of meaningful results. A stepwise binomial regression was performed to evaluate for variables predictive of receiving a prophylactic antibiotic prescription. The stepwise binomial model incorporated machine learning by randomly sampling 80% of the data for training and using the remaining 20% to test the model's predictive accuracy. With the help of automated stepwise variable selection, a list of final variables was incorporated into the model in hopes of achieving real-world predictive accuracy.

Results

Six hundred seventy-nine patients were identified. A total of 356 identified patients did not meet the inclusion criteria and were excluded from the study, resulting in a final cohort of 323 patients (Fig. 1). Demographic characteristics are presented in Table 1. Eight total infections were identified in the 323 patients (2.5% incidence of infection). Five of the 187 patients who received oral antibiotics developed infection (2.7% incidence of infection), whereas three of the 136 patients who did not receive antibiotics developed infection (2.2% incidence of infection). Incidence of infection ranged from 0% to 12.5% based on injury types, and these differences were not statistically significant (Table 2). Furthermore, 49.8% of the patients did not present for follow-up in one of our clinics, did not receive delayed antibiotic prescriptions within the MedStar system, and did not receive antibiotic prescription, present to an ED, or have surgery throughout identifiable episodes in our Health Information Exchange (Table 3). We considered lack of follow-up or an identifiable event to be "no infection."

Five infections occurred in the group treated with antibiotics, including one after amputation of a distal phalanx, two after open distal phalanx fractures (one suture abscess that was unroofed and one soft tissue infection that required incision and drainage in the clinic at a follow-up appointment), one open wound without

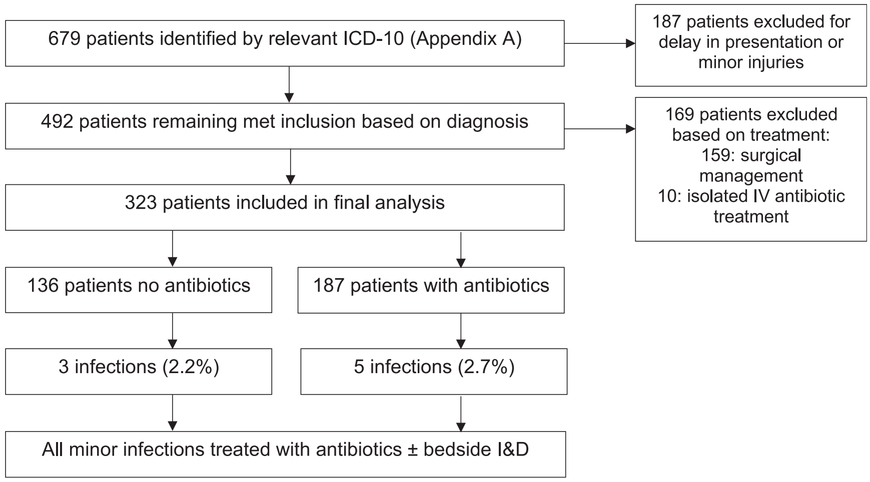

Figure 1. Inclusion criteria flow diagram. ICD-10, International Classification of Diseases, 10th Revision; I&D, incision and drainage; IV, intravenous.

Table 1
Summary of Patient Demographics and Injury Characteristics

Demographic characteristics	Results
Total no. of patients	323
Age (y)	39.03 (± 19)
BMI (kg/m^2)	27.9 (± 7)
Sex	
Male	238 (73.7%)
Female	85 (26.3%)
Encounter type	
Emergency	189 (58.5%)
Outpatient	131 (40.6%)
Observation	2 (<1%)
Inpatient	1 (<1%)
Tobacco use	
Never smoked/not exposed	233 (72.1%)
Current every day smoker	52 (16.1%)
Current some day smoker	4 (1.2%)
Former smoker	20 (6.2%)
Unknown exposure	14 (4.4%)
Diabetes	24 (7.4%)
Bleeding disorders	5 (1.5%)
Injury characteristics	
Fractures	165 (51.1%)
Amputation	74 (22.9%)
Nail bed injuries	42 (13%)
Other	42 (13%)
Location on hand	
Thumb	59 (18.3%)
Index finger	71 (22%)
Middle finger	83 (25.7%)
Ring finger	59 (18.3%)
Little finger	46 (14.2%)
Hand	5 (1.5%)
Open wound	
Yes	195 (60.4%)
Injury environment	
Domestic	233 (72.1%)
Work	84 (26%)
Other	6 (1.9%)
Injury mechanism (ICD code and explanation)	
W23 (caught, crushed, jammed, pinched in or between stationary objects)	226 (70%)
W31.2 (contact with powered woodworking and forming machines)	34 (10.5%)
W27 (contact with nonpowered hand tool)	13 (4%)
W29.8 (contact with other powered hand tools and household machinery)	13 (4%)
W20 (struck by thrown, projected, or falling object)	6 (1.9%)
W22.8 (striking against or struck by other objects)	5 (1.5%)
Other	26 (8%)

BMI, body mass index; ICD, International Statistical Classification of Diseases and Related Health Problems.

Table 2
Infection Rate by Injury Type and Antibiotic Regimen*

Antibiotics	Oral Antibiotic	No Antibiotic	Intravenous and Oral Antibiotic
Amputation			
No infection	50	9	14
Infection	1	0	0
% Infection	1.90%	0%	0%
Open fracture			
No infection	35	6	7
Infection	2	0	0
% Infection	5.7%	0%	0%
Closed fracture			
No infection	32	49	3
Infection	0	1	0
% Infection	0%	2%	0%
Nail bed injury isolated			
No infection	8	32	0
Infection	1	1	0
% Infection	12.5%	3%	0%
Open wound			
No infection	30	37	3
Infection	1	1	0
% Infection	3.22%	2.50%	0%

* Patients who had more than one injury type were classified under their most severe injury.

fracture or amputation, and one nail bed injury. Three infections occurred in the group of patients who received no prophylactic antibiotics, including one development of paronychia after thumb splinting for closed distal phalanx fracture, one open wound without fracture or amputation, and one nail bed injury. Of the eight total infections, four required incision and drainage in the clinic, and all resolved with an oral course of antibiotics.

We created a model of predictors of receiving an antibiotic prescription. Age, depressive disorders, open wound status, amputation, fractures, and encounter type were all found to be predictive factors of antibiotic-prescribing habits. Using stepwise binomial regression, our model was highly accurate and achieved an area under the receiver operating characteristic curve (AUC) of 0.86 (P < .001) (Table 4; Fig. 2). An AUC of 1 represents perfect discrimination. This AUC was achieved by using a random 80/20 data partition. The stepwise regression selected seven of the 49 possible variables (Table 4). Significant positive predictors of antibiotic prescribing included increased age (P = .003), depressive disorders (P = .024), open wound (P < .0001), amputation (P <

Table 3
Follow-up Percentage Based on Injury Type*

Follow-up Visits Based on Injury	Amputation	Open Fracture	Closed Fracture	Nail Bed Isolated	Open Wound
Follow-up	53	34	40	11	24
No follow-up	21	16	45	31	48
Percent follow-up	71%	68%	47%	26%	33%

* Combined follow-up was 49.8%.

Table 4
Regression Output for Predicting Antibiotics Prescriptions (AUC, 0.86; $P < .001$)

Term	Estimate	SE	Z Value	Pr(>|Z|)
Intercept	−2.56	0.47	−5.48	$P < .001$
Age (y)	0.02	0.01	2.96	$P = .003$
Bleeding disorders	−3.33	1.87	−1.78	$P = .075$
Depressive disorders	1.80	0.80	2.25	$P = .024$
Open wound	2.06	0.33	6.25	$P < .001$
Contamination status	1.02	1.22	0.84	$P = .40$
Amputation	1.95	0.47	4.19	$P < .001$
Fractures	1.71	0.34	4.98	$P < .001$
Chronic kidney disease	−1.18	0.75	−1.59	$P = .11$
Outpatient encounter	−0.98	0.31	−3.22	$P = .001$

.0001), and fractures ($P < .0001$). Encounter type was a significant negative predictor ($P = .001$).

Discussion

Our retrospective study of antibiotic practices after distal fingertip trauma that did not require surgical treatment focused on urgent care and ED management across our health system. We did not identify any meaningful associations between injury type, comorbidities, or antibiotic prophylaxis and development of infection. We observed an extremely low incidence of infection (2.5%) that impacted our overall ability to address the initial question as to whether prophylaxis impacts infection incidence. However, considering this overall very low incidence and minimal severity of the infections that did occur, our results raise questions about the usefulness of prophylactic antibiotics for these types of injuries.

Our study also demonstrated that physicians are prescribing antibiotics in a predictable way. Our model was able to predict with high accuracy whether a patient would receive antibiotics based on seven variables. Goltz et al[15] characterized the elements necessary for an ideal predictive model. Characteristics include excellent predictive accuracy (demonstrated by an AUC of >0.80 before external validation), model composition of exclusively preoperative variables, and easy integration with the electronic health record.[15] Our predictive model satisfied these criteria, achieving an AUC of 0.86. In future studies, the high predictive accuracy of our model may be applied to similar but larger data sets to investigate the isolated impact of antibiotic prescribing. By matching patients with similar prescription likelihoods but opposite infection outcomes, and assessing for incidence of infection, we may be able to determine that prophylactic antibiotics are relatively ineffective if infection incidence is similar between the matched pairs. This is an extremely useful tool for this area of research, as the complexity of each individual case makes a large RCT difficult to complete.

For simple hand injuries (lacerations, including flexor tendon injuries), studies have demonstrated no benefit to prophylactic antibiotics, and this is supported by the Murphy et al[5] meta-analysis examining the incidence of infection in simple hand lacerations requiring surgery. Several studies also examined the relationship between prophylactic antibiotic use and distal phalanx fractures.[13,14,16,17] A 2016 systematic review and meta-analysis conducted by Metcalfe et al[9] including four RCTs reported no difference in incidence of infection based on antibiotic prophylaxis in patients with open distal phalanx fractures. These findings are supported by a 2010 RCT of 1,340 patients conducted by Aydin et al,[18] which evaluated infection outcomes based on the classifications of hand injury requiring surgery. This study found no significant differences in infection incidence between placebo and prophylactic antibiotic groups among elective versus emergency procedures or crush versus dirty wounds.[18] Several studies suggest that antibiotic use makes no difference for open hand fractures; however, a systematic review and meta-analysis of 12 articles on open hand fractures (four prospective and eight retrospective, accounting for a total of 1,669 open fractures) found an association between administration of antibiotics and reduced incidence of infection.[19] In contrast to our study, this included fractures that required operative fixation. When specifically looking at fingertip amputations, our findings are consistent with those reported in previous reports including a RCT of 58 adult patients with fingertip amputations that found no difference and no infection in groups given a 3-day course of prophylactic antibiotics and those not given antibiotics.[8] Furthermore, there was no significant difference in comorbidities between the group that received antibiotic prophylaxis versus the group that did not. Other studies have also examined the role of prophylactic antibiotics in a surgical context. One prospective cohort study of 405 patients with emergency hand trauma suggested that postoperative antibiotic prophylaxis is not indicated in the management of open hand trauma as related to surgical site infection incidence.[20] Our distal fingertip trauma results are consistent with existing literature regarding antibiotic use and hand trauma, and we demonstrated that there are specific clinical elements (in our predictive model) that drive clinician antibiotic prescribing for injuries that seemingly do not need antibiotics, providing areas for further study and perhaps targeted interventions to improve stewardship.

This study has several limitations. As a retrospective cohort, we are limited to the data captured by the electronic health record in terms of injury characteristics and patient comorbidities. The study is also likely underpowered—as with such a very low incidence of infection (eight infections in our cohort), it is not reasonable for us to reach confidently meaningful results. Additionally, 49.8% of the patients were not seen during follow-up in one of our clinics and did not seek further care identifiable in our data systems after their initial injury. For the purposes of this study, we considered such lack of follow-up to be "no infection," but certainly, we may have missed some infections and/or additional treatments. In a retrospective study on nonsurgical trauma, this limitation is unavoidable because exclusion of those lost to follow-up would skew the results toward those who developed infections, had more complex issues, had better resources to attend follow-up, or likely a combination of things. Furthermore, we cannot answer perhaps the most important question: whether the patients who routinely receive antibiotics (open fracture, among others, as found in our predictive model) would still have the low infection incidence had none of them received antibiotics. Of the patients with an open fracture or amputation, only 15 of the 124 patients did not receive any antibiotics. However, we do note that none of these 15 patients

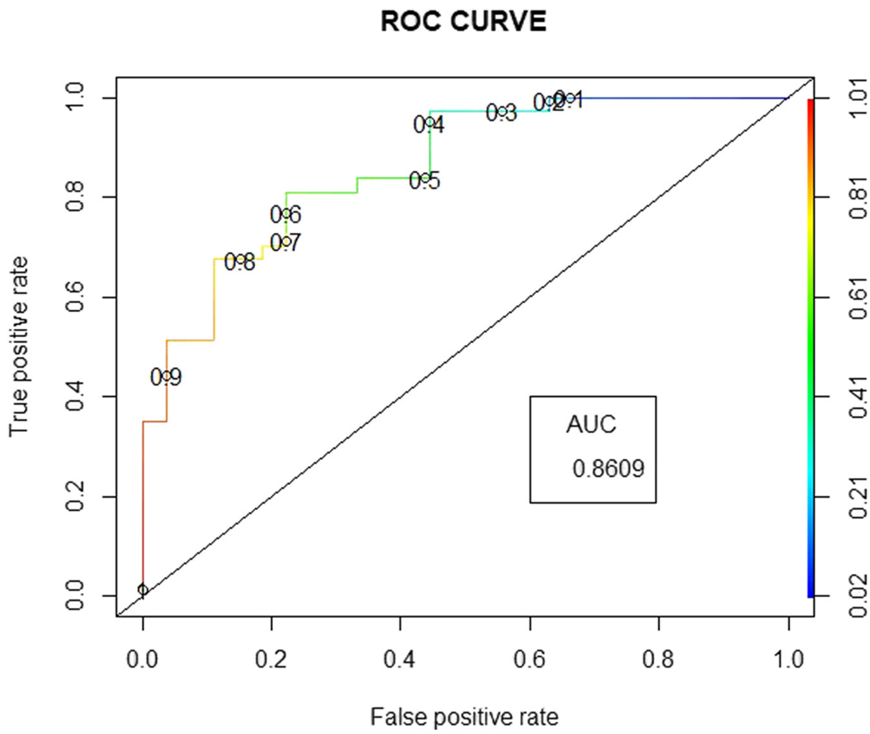

Figure 2. Receiver operating characteristic (ROC) curve demonstrating the accuracy of our model in predicting antibiotic prescribing.

developed an infection. The significant predictors our model identified do not tell us why predictors are significant; however, these results all provide areas for future study.

Although our study does not provide enough evidence to change practice guidelines regarding prophylactic antibiotic use in the setting of nonsurgical distal fingertip trauma, the extremely low incidence of infection and lack of any trends in our results should call this practice into further question. Providers should use a patient-centered approach and carefully consider the validity of their antibiotic-prescribing habits to determine whether they make sense for the individual patient.

There is no strong evidence to support antibiotic prophylaxis for these injuries. Further evaluation is necessary because widespread antibiotic use has its own risk profile related to AMR and potential adverse side effects. Since a large RCT on this topic is unlikely to be feasible, researchers need a way to control for the many confounding variables that impact this practice. Our prescribing model provides a method for predicting provider prescribing habits considering injury characteristics and patient comorbidities, providing areas for improvement and targeted investigation. We hope that future research contributes to creating evidence-based guidelines surrounding prophylactic antibiotic prescribing that are based on hand-specific research.

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