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Antimicrobial Prescribing Practices Following Publication of Guidelines for the Prevention of Infections Associated With Combat-Related Injuries

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Abstract

Background—Timely and limited antibiotic prophylaxis (postinjury antimicrobial therapy) targeting specific traumatic injuries is a well-recognized measure to lessen posttraumatic infection. Modern military combat injuries raise significant challenges because of complex multiple injuries and limited data derived directly from well-controlled trials to base recommendations. Expert consensus review of available evidence led to published guidance for selection and duration of antimicrobial therapy for combat-related trauma infection prevention. This analysis evaluates antibiotic-prescribing practices by military physicians in the operational theater relative to the published guidance.

Methods—Trauma history and infectious disease-specific inpatient care information is captured through the Joint Theater Trauma Registry along with a supplemental infectious disease module. Injury patterns are classified based on documented International Classification of Diseases-9th Revision codes with a composite assessment of each patient's injury pattern. Antimicrobial use categorized as prophylaxis is prescribed within the first 48 hours postinjury. Adherence to published guidance is reported along with patient characteristics and injury severity to assess for potential explanations of nonadherence.

Results—During June to November 2009, 75% of the 610 eligible trauma patients received antimicrobial prophylaxis. Adherence to the recommended antibiotic agent on the day of injury was in the range of 46% to 50% for the most common extremity injury patterns and 10% in penetrating abdominal injuries. Antibiotics were given in 39% of patients sustaining injuries that are recommendations to not receive antimicrobial prophylaxis.

Conclusions—This first evaluation of combat trauma-related antibiotic prophylaxis shows adherence levels comparable or superior to reported rates in civilian settings despite the austere, frequently mass casualty environment. Areas for interval surveillance and education-based strategies for improved adherence to practice guidance are identified.

Keywords

Antimicrobial prophylaxis; Combat infections; Practice guidelines; Adherence

Infections are well-recognized complications following traumatic injury.(1–3) Antibiotic prophylaxis (postinjury antimicrobial therapy) has been the focus of extensive research, and the findings of these investigations have led to clinical practice guidance (CPG) for a range of traumatic injuries with endorsement by several civilian organizations.(4–8) Combatrelated traumatic injury in modern warfare frequently introduces greater complexity because of multiple injuries with extensive tissue loss and disruption accompanied by wound contamination.^{9,10} In addition, the evidence base for antibiotic prophylaxis recommendations is significantly limited compared with civilian trauma settings. Given this challenge, military and civilian experts in trauma, infectious disease (ID), infection control, preventive medicine, and surgical specialties reviewed the available evidence in June 2007 leading to the development of guidelines for the prevention of infection related to combat injuries.(11) The consensus recommendations, which included antibiotic prophylaxis by specific injury type, were published in a Journal of Trauma supplement in March 2008.

At this time, the leadership group reconvened to assess the recommendations based on updated evidence with an emphasis on publications derived from current combat operations. As guidance is developed and disseminated, it is critical to assess adoption of recommendations similar to investigations within civilian settings related to antibiotic prophylaxis guidelines in general surgery.(12–14) The purpose of this analysis is to evaluate the antibiotic prescribing practices by military physicians in the operational theater relative to the published guidance providing a benchmark for ongoing assessments of adoption of the published guidance.

METHODS

Summary Design

The CPG focus for posttrauma antimicrobial prophylaxis is timely administration for a discrete limited duration targeting antimicrobial coverage based on the specific traumatic injury and infection risk.(11) Given this focus, the analysis is restricted to antibiotic administration occurring either on the day of injury or the following day to account for a delay in capturing documentation in a combat environment. Patient selection requires documented injury in the operational theater during the current military conflicts in Iraq or Afghanistan, Operations Iraqi Freedom or Operations Enduring Freedom (OIF/OEF). In addition, trauma patients eligible for inclusion in the analysis must be active-duty personnel or Department of Defense (DoD) beneficiary, 18 years of age, wounded or injured during deployment requiring return via Landstuhl Regional Medical Center (LRMC), Landstuhl, Germany (admission between June 1 and November 30, 2009).

Data Collection

Patient trauma history, injury severity scoring, and surgical management are obtained through selected data elements retrieved from the DoD Joint Theater Trauma Registry (JTTR).⁽¹⁵⁾ The JTTR was established by the Assistant Secretary of Defense for Health Affairs as a means to provide an effective performance improvement tool to assess combat casualty care epidemiology and treatment outcomes. An ID module to augment the JTTR was developed to capture infection-specific data throughout levels of care at participating hospitals. This ID-specific information includes diagnoses, antimicrobial therapy, and infection outcomes. The JTTR/ID module captures data on all active-duty military trauma patients admitted to LRMC, Landstuhl, Germany, and participating military medical centers in the United States (National Naval Medical Center, Bethesda, MD; Brooke Army Medical Center, Fort Sam Houston, TX; or Walter Reed Army Medical Center, Washington, DC). The overarching project for this analysis is the DoD-Department of Veterans Affairs Trauma Infectious Disease Outcomes Study project, approved by the Uniformed Services University Institutional Review Board, which is an observational cohort study of short- and long-term ID outcomes following a deployment-related traumatic injury using hospitalization data captured through the JTTR and the ID module. Analyses are based on deidentified JTTR/ID module data.

Study Definitions/End Points

Trauma care within the military is typically described based on levels and is defined as follows: Role 1 (also termed Level I or Echelon I), point of injury/first responder care within the combat zone; Role 2, resuscitation and surgical stabilization at medical units (not hospitals) within the combat zone (which may be augmented with surgical assets); Role 3, medical/surgical care at combat support or other theater hospitals (highest available care in the combat zone); Role 4, regional medical center care located in communication zone (e.g., LRMC); and Role 5, definitive treatment/rehabilitation at major tertiary care medical centers in the United States.

The JTTR captures International Classification of Diseases-9th Revision codes for any injury sustained by patients during a traumatic incident. Separate International Classification of Diseases-9th Revision codes representing similar injury types such as “skin/soft tissue injury with closed fractures,” “skin/soft tissue injury with open fractures, exposed bone, or open joints,” “thoracic cavity (penetrating injuries),” or “abdominal (penetrating injury)” are further grouped into injury categories (Table 1). The majority of patients have two or more injury categories requiring further classification to accurately represent the composite injury. The overall patient injury pattern is classified into either solitary or multiple injuries as detailed in Table 1. Severity scoring systems are used to provide internal and external comparability of this traumatized patient population both for initial assessment of the traumatic injury and subsequent interval health assessments. The Injury Severity Score (ISS) uses anatomic classification for injury classification and severity scoring.⁽¹⁶⁾ Interval assessments of general health are undertaken using the Sequential Organ Failure Assessment.⁽¹⁷⁾ The Sequential Organ Failure Assessment score is composed of scores from six organ systems, graded from 0 to 4 according to the degree of dysfunction/failure.

Antimicrobial prophylactic regimen classification is detailed in Table 2 and is based on targeting the suspect microbial contamination related to traumatic event. The regimen classification was compared with the published guidance to determine whether prescribed antimicrobial agents met or did not meet the recommendation. To account for delay in documentation in a combat setting, both the day of injury and the day of injury plus the next day are evaluated separately. The antimicrobial regimen duration (based only on documented use on day of injury) was classified as follows: 1 day, >1 day but 3 days, >3 days but 5 days, >5 days, or unknown (no regimen [all or a component] stop date).

ID events are classified using a combination of clinical findings, laboratory and other test results, as previously described,(1) available through medical record review, applying standardized definitions for nosocomial infections used by the National Healthcare Safety Network.(18) In addition, a physician's clinical diagnosis in the absence of meeting a priori defined criteria was also counted as an ID event provided there was initiation of directed antimicrobial therapy with continuation of this therapy for 5 days. An ID event is excluded if the medical record states an alternative diagnosis is determined and accompanied by discontinuation of directed antimicrobial therapy.

Statistical Analysis

Statistical analyses included descriptive statistics shown as counts (percentages) for categorical variables and medians (interquartile ranges) for continuous variables. Group comparisons, such as for potential explanatory factors of adherence to guidance, were conducted using the Wilcoxon-Mann-Whitney test of no difference between groups for continuous variables. Association between adherence and categorical factors was tested via Fisher's exact test.

RESULTS

Study Population Characteristics

The total patient population based on trauma patient admissions (active duty or DoD beneficiary and adult) to LPMC from June through November 2009 was 703. Among these, patient selection for inclusion in the analysis required available JTTR injury data (N = 687; 97.7%). Additional exclusions were as follows: non-OIF/OEF trauma (N = 35), identical dates of injury and LPMC admission (N= 19), and discordant JTTR injury dates >1 day (N = 25). Overall, there were 77 patients excluded (some had >1 basis for exclusion), leaving 610 eligible patients (86.8%) selected for analysis. Demographic and clinical characteristics of the evaluable patient population are detailed in Table 3. The population is predominantly young enlisted men with the majority sustaining a blast injury in Afghanistan. Approximately 4.1% developed an infection while at LPMC, and 30.2% had at least one incident infectious complication in the United States, among the 50% who continued to be monitored following transfer to a participating medical center.

Injury Patterns

A total of 5,893 individual injuries are documented in the 610 evaluable patients (Table 4). Extremity injuries (57%) account for the majority. Further classification on a per patient

basis for the overall injuries demonstrates the following common patterns (Table 5): no open wounds/no fractures (30.7%), no open and/or open wounds plus closed fractures (29.8%), no open and/or open wounds plus open fractures (18.5%), and penetrating abdominal wounds $\pm$ other wounds (9.5%).

Antimicrobial Regimens

The most common antimicrobial regimens irrespective of injury pattern are captured by limiting to prescription either on the day of injury or day of injury plus the next day. Overall, 151 (24.8%) patients did not receive an antibiotic in the first 48 hours. Common antimicrobial regimens used for the day of injury receiving antibiotics are as follows: none (38.8%), cefazolin alone (29.7%), amoxicillin/clavulanate (intravenous [IV]; 5.3%), cefazolin plus levofloxacin (5.3%), cefazolin plus gentamicin (2.2%), clindamycin (IV) alone (2.2%), and cefazolin plus piperacillin/tazobactam (1.1%). The agents prescribed on day of injury +1 are as follows: none (33.9%), cefazolin alone (28.7%), cefazolin plus levofloxacin (11.6%), amoxicillin/clavulanate (IV; 3.6%), clindamycin (IV) alone (3.3%), amoxicillin/clavulanate (IV; 1.6%), cefazolin plus levofloxacin (1.3%), and cephalixin (orally; 1.3%). Antimicrobial use is captured on a per calendar day basis so it is not possible to discriminate between regimens that are stopped and/or started on the same day.

Antimicrobial Prescribing for Particular Injury Patterns

Overall, adherence to published CPG, based on the antimicrobial therapy prescribed on the day of injury, fell in the range of 45.6% to 61.0% across the selected most common injury patterns (Table 6). Notably, an exception is the overall adherence rate among penetrating abdominal injuries (typically with other injuries), which is consistent with practice guidance in only 5.2%. Most commonly, these patients with penetrating abdominal injury received regimens categorized as gram-positive monotherapy (58%) or gram-positive plus enhanced gram-negative (18%) and failed to meet recommendation due to lack of anaerobic coverage. A high number of patients (23.0%–36.8%) sustaining injuries meeting criteria for antimicrobial prophylaxis had no documented antibiotics received on the day of injury. In contrast, patients sustaining injuries that do not have recommendations for antimicrobial prophylaxis (39.0%) did receive antibiotics. Most often, these patients received regimens categorized as gram-positive monotherapy (60%) or gram-positive plus enhanced gram-negative (21%).

The multiple soft tissue injuries with open fracture(s), as shown in Table 6, had a 50.4% adherence to the published guidance; however, this allows for the inclusion of enhanced gram-negative antimicrobial coverage, which accounts for 35% of the overall “adherent” practice. If excluded, as done in the published guidance although included in other guidance, then “consistent with the CPG” for this injury pattern decreases to 33%. The use of enhanced gram-negative coverage (44%) was also observed in patients receiving regimens not recommended following multiple soft tissue injuries with closed fracture(s), in addition to common use of amoxicillin/clavulanate or piperacillin/tazobactam monotherapy (44%). The other antibiotics that were not consistent with published guidance in the patients with multiple soft tissue injuries with open fracture(s) included amoxicillin/clavulanate

monotherapy (47%) or gram-positive plus enhanced gram-negative $\pm$ other antibiotics (40%).

The inclusion of the next day along with the day of injury (Table 6) provides increased capture of prophylactic antibiotic documentation. The broader window leads to higher levels of adherence for all injury patterns, from the day of injury range among common extremity injuries of 45.6%–50.4% to 64.3%–78.8%. Again, the exception is injuries including penetrating abdominal trauma, which marginally increases to 10.3% consistency with published guidance. In the wider time period, there is also a decrease (from 61.0% to 51.9%), in a nonadherence direction, in the number of patients not receiving antibiotics (as is recommended) for traumatic injuries not meeting criteria for antimicrobial prophylaxis.

The antimicrobial therapy duration based on selected injury patterns stratified by the initial antibiotic selection is detailed in Table 7. Patients receiving antimicrobial prophylaxis for traumatic injuries not meeting criteria for antibiotics demonstrate a near-uniform distribution across the following range (after removing missing data): 1 day (37%), 2 days to 3 days (30%), and 4 days (33%). In patients sustaining injury types recommended for antimicrobial prophylaxis, there are relatively high numbers as previously stated that do not have documented antibiotic use. Given the common feature of extremity trauma in this population, a reasonable approximation to assess adherence to the recommended antimicrobial duration can use the 72-hour time period stated for either closed or open fractures. Combining all patients with evaluable data in Table 6 sustaining an injury meeting criteria for antimicrobial prophylaxis use, irrespective of initial antibiotic selection, shows that 56% received antibiotics 3 days and 44% for 4 days. Stratifying by initial antibiotic selection demonstrates shorter (< 3 days) duration in patients receiving other than CPG compared with patients prescribed recommended regimens (68% vs. 48%).

Factors Associated With Antimicrobial Prescribing Consistent With Particular Injury Patterns

The combat zone, mechanism of injury, and indicators of injury severity (ISS or admitting unit at LRMC) are evaluated for association with postinjury antimicrobial therapy consistency with published CPG (Tables 7 and 8). In Table 8, the analysis is restricted to patients with traumatic injuries recommended to receive antibiotic(s). An overall assessment of all patients demonstrates significantly higher adherence to published guidance in patients sustaining injury in support of OIF when compared with OEF ($p = 0.008$). There was no difference based on mechanism of injury or injury severity. Restricting the comparison to patients receiving care not consistent with CPG (none vs. other antibiotics) also demonstrated a difference based on theater of operations. Antibiotic use (although not consistent with guidance) was much more likely in patients with blast injuries ($p = 0.006$) or if admitted to the LRMC intensive care unit ($p = 0.013$) when compared with patients not receiving any antibiotics (also inconsistent with guidance).

In Table 9, the analysis is restricted to patients with traumatic injuries not recommended to receive antibiotic(s). Higher rates of consistent use of guidance in these patients were observed in those injured in support of OIF when compared with OEF ($p = 0.014$). Patients with measures suggesting increased injury severity, ISS ($p = 0.0012$) and LRMC intensive

care unit admission ($p = 0.0015$), were significantly associated with the use of any antimicrobial for prophylaxis despite not having an injury pattern meeting criteria for recommended prophylaxis.

DISCUSSION

Efforts to effectively implement CPG are influenced by several factors including the attributes and quality of the evidence supporting the guidance, barriers and/or facilitators to practice change, and effectiveness of implementation and dissemination strategies.(19–21) Guidelines for the prevention of infections associated with combat-related injuries were published in March 2008 refining available guidance in a very comprehensive approach using the Infectious Diseases Society of America/US Public Health Service rating system. (11) Notably, the consensus recommendations were published in a Journal of Trauma supplement approximately 6 months before the time period evaluated in this analysis. It is unknown as to the extent this information became known to providers in theater. In addition, the published guidance adds to other published guidance, with some differences in specific antimicrobial recommendations, focusing on civilian noncombat trauma populations which may explain a component of the observed deviation from guidance.(4,7)

On the basis of this cross-sectional 6-month period in 2009, adherence to the recommended antimicrobial agents for the most common injury patterns, those involving extremity trauma, was observed to be approximately 50% to 60%. Since this published guidance is the first comprehensive effort of this type, specifically for combat-related trauma, there is no prior comparison within military health care during wartime. There are several published studies assessing adherence to antibiotic prophylaxis guidelines in general surgery,(12–14) and more specific evaluation within orthopedic trauma civilian populations.(22) Many of these studies evaluating elective surgeries in either clean or clean contaminated conditions investigate factors influencing antibiotic prophylaxis for the prevention of surgical site infections.(14) Twelve of the studies reviewed were investigations pre- and postintervention in an attempt to improve adherence to published guidance in areas such as appropriateness of antibiotic selection, timing of administration, and duration of use. The preintervention adherence levels documented for several factors related to application of the published guidance were commonly in the range of 30% to 50%. In an assessment in an orthopedic civilian trauma population in Canada, the adherence preoperative was very high at 93%; however, postoperative continuation was low at 32%.(22) In our study, a common observation was use of antimicrobial prophylaxis in 36% of patients sustaining injuries that do not have recommendations for antimicrobial prophylaxis. This finding has also been reported in 19% of a civilian surgery population.(12) In this same study, the overall adherence to recommended guidelines was 36%, which was lower than observed in our study. The civilian settings do not have the same austere and challenging environment in which military providers must function during combat operations; however, despite this, the findings certainly highlight the challenges with nonadherence.

Limitations in this analysis include low statistical power to fully assess reasons for discordant antimicrobial regimens from the guidance; however, preliminary analysis suggests differences based on theater and injury severity and warrant further evaluation.

Expanded analyses covering longer time periods will allow for more precision on adherence levels and investigation of explanatory factors. In addition, the completeness of documentation, such as antibiotic dosing, in an up-tempo environment with patients frequently being transferred between medical facilities is unknown. The ability to discriminate antimicrobial use for prophylaxis versus empiric early-treatment posttrauma limits the ability to evaluate antibiotic duration use compared with published guidance, particularly as the time extends longer than 72 hours postinjury.

The findings in this combat military setting warrant improvement while providing an encouraging benchmark relative to previous reports in civilian settings. As revised guidance is developed, it will become important to provide effective dissemination to end users, adequate training, and monitoring for adoption via audit and feedback strategies.¹⁹ Specific areas that demonstrated deviation from the published guidance, such as the inclusion of enhanced gram-negative antimicrobial coverage in both the open and closed fracture injury patterns, are important targets for continuous quality improvement monitoring. In addition, to interval reassessments, it is also critical to assess short- and long-term clinical infectious complications relative to prophylactic antimicrobial regimens to further improve the available evidence base and optimize prevention strategies.

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References

1. Tribble DR, Conger NG, Fraser S, et al. Infection-associated clinical outcomes in hospitalized medical evacuees following traumatic injury— Trauma Infectious Disease Outcome Study (TIDOS). *J Trauma*. 2011; 71:S33–S42. [PubMed: 21795875]
2. Murray CK, Hinkle MK, Yun HC. History of infections associated with combat-related injuries. *J Trauma*. 2008; 64:S221–S231. [PubMed: 18316966]
3. Cirillo VJ. Two faces of death: fatalities from disease and combat in America's principal wars, 1775 to present. *Perspect Biol Med*. 2008; 51:121–133. [PubMed: 18192771]
4. Hauser CJ, Adams CA Jr, Eachempati SR. Council of the Surgical Infection Society. Surgical Infection Society guideline: prophylactic antibiotic use in open fractures: an evidence-based guideline. *Surg Infect (Larchmt)*. 2006; 7:379–405. [PubMed: 16978082]

5. Jaeger M, Maier D, Kern WV, Südkamp NP. Antibiotics in trauma and orthopedic surgery—a primer of evidence-based recommendations. *Injury*. 2006; 37(suppl 2):S74–S80. [PubMed: 16651075]
6. Luchette FA, Barrie PS, Oswanski MF, et al. Practice management guidelines for prophylactic antibiotic use in tube thoracostomy for traumatic hemopneumothorax: the EAST Practice Management Guidelines Work Group. Eastern Association for Trauma. *J Trauma*. 2000; 48:753–757. [PubMed: 10780613]
7. Luchette FA, Borzotta AP, Croce MA, et al. Practice management guidelines for prophylactic antibiotic use in penetrating abdominal trauma: the EAST Practice Management Guidelines Work Group. *J Trauma*. 2000; 48:508–518. [PubMed: 10744294]
8. Wilson RF, Nichols RL. The EAST Practice Management Guidelines for Prophylactic Antibiotic Use in Tube Thoracostomy for Traumatic Hemopneumothorax: a commentary. Eastern association for trauma. *J Trauma*. 2000; 48:758–759. [PubMed: 10780614]
9. Covey DC, Aaron RK, Born CT, et al. Orthopaedic war injuries: from combat casualty care to definitive treatment: a current review of clinical advances, basic science, and research opportunities. *Instr Course Lect*. 2008; 57:65–86. [PubMed: 18399571]
10. Hayda RA, Mazurek MT, Powell ET Iv, et al. From Iraq back to Iraq: modern combat orthopaedic care. *Instr Course Lect*. 2008; 57:87–99. [PubMed: 18399572]
11. Hospenthal DR, Murray CK, Andersen RC, et al. Guidelines for the prevention of infection after combat-related injuries. *J Trauma*. 2008; 64:S211–S220. [PubMed: 18316965]
12. Tourmousoglou CE, Yiannakopoulou ECh, Kalapothaki V, Bramis J, St Papadopoulos J. Adherence to guidelines for antibiotic prophylaxis in general surgery: a critical appraisal. *J Antimicrob Chemother*. 2008; 61:214–218. [PubMed: 17999981]
13. Prospero E, Barbadoro P, Marigliano A, Martini E, D’Errico MM. Perioperative antibiotic prophylaxis: improved compliance and impact on infection rates. *Epidemiol Infect*. 2010:1–6.
14. Gagliardi AR, Fenech D, Eskicioglu C, Nathens AB, McLeod R. Factors influencing antibiotic prophylaxis for surgical site infection prevention in general surgery: a review of the literature. *Can J Surg*. 2009; 52:481–489. [PubMed: 20011184]
15. Eastridge BJ, Jenkins D, Flaherty S, Schiller H, Holcomb JB. Trauma system development in a theater of war: experiences from operation Iraqi freedom and operation enduring freedom. *J Trauma*. 2006; 61:1366–1372. discussion 1372–1373. [PubMed: 17159678]
16. Champion HR, Holcomb JB, Lawnick MM, et al. Improved characterization of combat injury. *J Trauma*. 2010; 68:1139–1150. [PubMed: 20453770]
17. Ferreira FL, Bota DP, Bross A, Mélot C, Vincent JL. Serial evaluation of the SOFA score to predict outcome in critically ill patients. *JAMA*. 2001; 286:1754–1758. [PubMed: 11594901]
18. Horan, TC., Gaynes, RP. Surveillance of nosocomial infections. In: Mayhall, CG., editor. *Hospital Epidemiology and Infection Control*. 3. Philadelphia, PA: Lippincott Williams & Wilkins; 2004. p. 1659-1702.
19. Grol R, Grimshaw J. From best evidence to best practice: effective implementation of change in patients’ care. *Lancet*. 2003; 362:1225–1230. [PubMed: 14568747]
20. Davis DA, Taylor-Vaisey A. Translating guidelines into practice. A systematic review of theoretic concepts, practical experience and research evidence in the adoption of clinical practice guidelines. *CMAJ*. 1997; 157:408–416. [PubMed: 9275952]
21. Larson E. Status of practice guidelines in the United States: CDC guidelines as an example. *Prev Med*. 2003; 36:519–524. [PubMed: 12689796]
22. Lundine KM, Nelson S, Buckley R, Putnis S, Duffy PJ. Adherence to perioperative antibiotic prophylaxis among orthopedic trauma patients. *Can J Surg*. 53:367–372. [PubMed: 21092428]

TABLE 1
Traumatic Injury Classification by Individual Anatomic Site and by Patient Injury Pattern

Individual Injury Category*	Patient Injury Pattern
	Solitary injury category
Skin/soft tissue + closed fracture(s)	• Skin/soft tissue + closed fracture(s)
Skin/soft tissue + open fracture(s), exposed bone, or open joints	• Skin/soft tissue + open fracture(s), exposed bone, or open joints
Thoracic cavity (penetrating)	• Thoracic cavity (penetrating)
Abdomen (penetrating)	• Abdomen (penetrating)
Maxillofacial—open fracture or fracture with foreign body or fixation device	• Maxillofacial—open fracture or fracture with foreign body or fixation device
CNS—penetrating brain injury	• CNS—penetrating brain injury
CNS—penetrating spinal cord injury	• CNS—penetrating spinal cord injury
Eye injury, burn, or abrasion	• Eye injury, burn, or abrasion
Eye injury (penetrating)	• Eye injury (penetrating)
Burns	• Burns
Closed skull/facial bone fracture	• Other (solitary injury)
Other closed fracture (no open wound)	Multiple injury categories (selected)
Other musculoskeletal injury (no open wound)	• Soft tissue/fractures (no open) 2 sites
Nonpenetrating thoracic injury	• Soft tissue/fractures (1 open) 2 sites
Nonpenetrating abdominal injury	• Thoracic cavity (penetrating) + soft tissue/fractures (any)
Vascular injury	• Abdomen (penetrating) + soft tissue/fractures (any)
Other injury	• Thoracic + abdomen ± soft tissue/fractures (any)
	• Maxillofacial + soft tissue/fractures (any)
	• Maxillofacial + CNS (brain)
	• CNS (spinal cord) + Abdomen
	• CNS + abdomen + thoracic + maxillofacial ± soft tissue/fractures (any)
	• Other (multiple injury)

CNS, central nervous system.

* Categorized based on ICD-9 code.

TABLE 2

Antimicrobial Prophylactic Regimen Classification

Microbial Contamination Coverage Posttrauma	Antibiotic Regimen
Gram-positive bacteria (not anaerobes)	Cefazolin monotherapy (also includes alternatives such as clindamycin or vancomycin [penicillin allergy])
Gram-positive bacteria (not anaerobes) + enhanced coverage of gram-negative bacteria	Agents used for gram-positive monotherapy (above) + either fluoroquinolone or aminoglycosides
Gram-positive bacteria + gram-negative bacteria + anaerobic coverage (focus on abdominal injury)	Range of “acceptable” options includes carbapenem monotherapy, other broad-spectrum penicillin class monotherapy (i.e., piperacillin/tazobactam), moxifloxacin monotherapy, or fluoroquinolone + metronidazole
Gram-positive bacteria + gram-negative bacteria + anaerobic coverage (focus on head/neck injury)	Broad-spectrum penicillin class monotherapy (amoxicillin/clavulanate or ampicillin/sulbactam)
Gram-positive bacteria + anaerobic coverage ± gram-negative bacteria (focus on CNS injury)	Gram-positive regimen (as noted above) + metronidazole + (fluoroquinolone or aminoglycoside) or cefuroxime monotherapy

CNS, central nervous system.

In addition, given the common occurrence of initial care at a non-US field medical facility in Afghanistan followed by transfer to US facilities, it was necessary to consider antimicrobial formulations not available in US facilities that are acceptable “transition” regimen(s). Usually, this was a single dose of intravenous amoxicillin/clavulanate followed on the same or next day by a recommended regimen.

Demographic and Clinical Characteristics for Patients Admitted to Landstuhl Regional Medical Center After Traumatic Injury in Support of OIF/OEF
June to November 2009

TABLE 3

Characteristic	Total (%)
JTTR registrants (No. with available data)	610
Operation Iraqi Freedom	150 (24.6)
Operation Enduring Freedom	460 (75.4)
Male	596 (97.7)
Age, median (IQR)	24 (21, 29)
Mechanism of injury	
Gunshot wound	105
Motor vehicle crash	106
Blast	382
Other	145
Injury Severity Score, ISS 2005, median (IQR)	9 (5, 17)
ICU admission	188 (30.8)
Admission SOFA, mean (SD)	1.94 (3.04)
Abnormal SOFA score component	
Respiration ($\text{PaO}_2/\text{FiO}_2 < 400$)	71 (11.6)
Coagulation (platelets $< 150 \times 10^3/\text{mm}^3$)	195 (32.0)
Hepatic function (bilirubin $> 1.2 \text{ mg/dL}$)	131 (21.5)
Cardiovascular (MAP $< 70 \text{ mm Hg}$)	106 (17.4)
Neurologic Function (Glasgow coma scale < 15)	132 (21.6)
Renal Function (creatinine $> 1.2 \text{ mg/dL}$)	57 (9.3)
Mechanical ventilation (%)	111 (18.2)
Role 3/4, 24 h blood transfusion 10 units (%)	40 (6.6)
Incident infection rate (onset at Role 4)	25/610 = 4.1%
Incident infection rate (onset at Role 5)	101/334 = 30.2%

Role (level of care), normal composite score = 0, (17)

TABLE 4

Total Number of Injuries (Multiple Occurrences Within Individual Patients) by Injury Category Classification

Injury	No. of ICD-9 Injuries
Skin, soft tissue, no open fractures	1,593
Other closed fracture (no open wound)	1,012
Other injury	957
Skin, soft tissue, with open fractures, exposed bone, or open joints	754
Closed skull/facial bone fracture	279
Burns	232
Other musculoskeletal injury (no open wound)	166
Vascular injury	152
Nonpenetrating thoracic injury	135
Abdomen (penetrating)	120
Nonpenetrating abdominal injury	119
Central nervous system—penetrating brain injury	85
Maxillofacial—open fracture or fracture with foreign body or fixation device	84
Eye injury, burn, or abrasion	73
Thoracic cavity (penetrating)	48
Central nervous system—penetrating spinal cord injury	46
Eye injury (penetrating)	38

Most Common Patient Injury Patterns for Patients Admitted to Landstuhl Regional Medical Center After Traumatic Injury in Support of OIF/OEF June to November 2009

TABLE 5

Injury Pattern	No. (%)
No open injuries (solitary or multiple)	187 (30.7)
Multiple/solitary soft tissue/fractures (no open)	182 (29.8)
Multiple/solitary soft tissue/fractures (open fractures, exposed bone, or open joints)	113 (18.5)
Multiple abdomen (penetrating)	58 (9.5)
other injuries (may include open fractures, etc.)	
Multiple maxillofacial injuries soft tissue/fractures (any)	37 (6.1)
Multiple maxillofacial CNS (penetrating)	15 (2.5)
Multiple thoracic cavity (penetrating) soft tissue/ fractures (any)	15 (2.5)
Solitary burns	3 (0.5)

Antimicrobial Therapy for Prevention of Infection in Combat-Related Trauma: Adherence to Published Clinical Practice Guideline (CPG)

TABLE 6

	Antimicrobial Prophylaxis (Started Day of Injury)						
Injury Pattern	None (%)	Preferred Agent(s)	Alternate Agent(s)	Enhanced Gram-Negative Coverage	Consistent With CPG (%)	Other Antibiotics (%)	Total
Multiple or solitary other injuries (no open)							
DOI	114 (61.0)	/	/	/	114 (61.0)	73 (39.0) *	187
DOI + 1	97 (51.9)	/	/	/	97 (51.9)	90 (48.1)	
Multiple-soft tissue/fractures (no open)							
DOI	67 (36.8)	79	4	NA	83 (45.6)	32 (17.6) ‡	182
DOI + 1	35 (19.2)	110	7	NA	117 (64.3)	30 (16.5)	
Multiple-soft tissue/fractures (open)							
DOI	26 (23)	35	2	20 (17.7)	57 (50.4)	30 (26.5) ‡	113
DOI + 1	7 (6.2)	37	2	50	89 (78.8)	17 (15.0)	
Multiple-abdomen (penetrating) ± range of other injuries							
DOI	15 (25.9)	3	NA	NA	3 (5.2)	40 (69.0) §	58
DOI + 1	6 (10.3)	6	NA	NA	6 (10.3)	46 (79.3)	
Multiple-maxillofacial + soft tissue/fractures (any)							
DOI	8 (21.6)	15	1	2	18 (48.6)	11 (29.7) ¶	37
DOI + 1	3 (8.1)	16	7	4	27 (73.0)	7 (18.9)	

DOI, day of injury.

^{*} Other regimens (based on DOI): gram-positive monotherapy (60%), gram-positive + enhanced gram-negative (21%).[‡] Other regimens (based on DOI): gram-positive + enhanced gram-negative (44%), amoxicillin/clavulanate or piperacillin/tazobactam monotherapy (44%).[‡] Other regimens (based on DOI): amoxicillin/clavulanate monotherapy (47%), gram-positive + enhanced gram-negative ± other antibiotics (40%).[§] Other regimens (based on DOI): gram-positive monotherapy (58%), gram-positive + enhanced gram-negative (18%).[¶] Other regimens (based on DOI): amoxicillin/clavulanate monotherapy (36%), gram-positive + enhanced gram-negative (36%).

TABLE 7

Antimicrobial Therapy Duration for Selected Injury Patterns by Antibiotic Agent Adherence to Published Guidance

Injury Pattern	Antimicrobial Therapy Duration (From Day of Injury) (%)						
	Antibiotic Selection Consistent With CPG	None	1 d	2-3 d	4-5 d	>5 d	Unknown
Multiple/solitary other nonopen injuries (N = 187)	Yes (n = 114)	114 (100)	NA	NA	NA	NA	NA
	No (n = 73)	/	25 (34)	20 (27)	7 (10)	15 (21)	6 (8)
Multiple soft tissue/closed fractures (n = 182)	Yes (n = 83)	/	20 (24)	30 (36)	10 (12)	18 (22)	5 (6)
	No (n = 99)	67 (68)	4 (4)	17 (17)	3 (3)	4 (4)	4 (4)
Multiple soft tissue/open fractures (n = 113)	Yes (n = 57)	/	7 (12)	9 (16)	7 (12)	27 (47)	7 (12)
	No (n = 56)	26 (46)	4 (7)	18 (32)	1 (2)	7 (13)	0 (0)
Abdomen (penetrating) ± other injuries (n = 58)	Yes (n = 3)	/	0 (0)	0 (0)	0 (0)	3 (100)	0 (0)
	No (n = 55)	15 (27)	4 (7)	20 (36)	4 (7)	10 (18)	2 (4)
Maxillofacial + soft tissue/closed fractures (any) (n = 37)	Yes (n = 18)	/	2 (11)	3 (17)	5 (28)	8 (44)	0 (0)
	No (n = 19)	8 (42)	0 (0)	5 (26)	3 (16)	2 (11)	1 (5)

The following durations are recommended for antimicrobial therapy for prevention of infection: multiple/solitary other nonopen injuries (no antibiotic recommended); multiple-soft tissue/closed or open fractures (72 h); abdomen (penetrating) ± other injuries (24 h after definitive cleaning); maxillofacial + soft tissue/closed fractures (any) (24 h or 72 h if closed/open fractures).

TABLE 8

Patient Characteristics by Consistency With Published Clinical Practice Guidance (CPG) for Postinjury Prophylactic Antibiotics (First 48 h) (Restricted to Patients With Traumatic Injuries Recommended to Receive Antibiotics)

Factor	Antibiotic Regimen Consistent With CPG (N = 239)	Not Consistent With CPG			Comparisons (p)	
		No Antibiotics Given (N = 51)	Antibiotics Other Than Recommended (N = 100)		Overall Consistent With CPG (Yes vs. No)	Not Consistent With CPG Only (None vs. Other Antibiotics)
Iraq theater (%)	56 (74.6)	11 (14.7)	8 (10.7)	Theater deployment	0.008	0.017
Afghanistan theater (%)	183 (58.1)	40 (12.7)	92 (29.2)			
Mechanism of injury						
Blast	181 (61.2)	32 (10.8)	83 (28.0)	Mechanism of Injury	0.92	0.006
Other	58 (61.7)	19 (20.2)	17 (18.1)			
Injury severity score, median (IQR)	10 (5, 17)	9 (5, 17)	10 (6, 22)	ISS	0.09	0.09
LRMC ICU admission (%)	80 (60.2)	11 (8.3)	42 (31.6)	LRMC admitting unit	0.74	0.013
LRMC ward admission (%)	159 (61.9)	40 (15.6)	58 (22.6)			

Patient Characteristics by Consistency With Published Clinical Practice Guidelines (CPG) for Postinjury Prophylactic Antibiotics (First 48 h) (Restricted to Patients With Traumatic Injuries NOT Recommended to Receive Antibiotics)

TABLE 9

Factor	Consistent With CPG (No Antimicrobial) (N = 97)	Other Than CPG (Any Antimicrobial) (N = 90)	<i>p</i>
Iraq theater (%)	45 (63.4)	26 (36.6)	0.014
Afghanistan theater (%)	52 (44.8)	64 (55.2)	
Mechanism of injury			
Blast	31 (46.3)	36 (53.7)	0.25
Other	66 (55.0)	54 (45.0)	
Injury severity score, median (IQR)	6 (5, 13)	9 (5, 12)	0.0012
LRMC ICU admission (%)	8 (25.8)	23 (74.2)	0.0015
LRMC ward admission (%)	89 (57.1)	67 (43.0)	