Guidelines for the Prevention of Infections Associated With Combat-Related Injuries: 2011 Update

Endorsed by the Infectious Diseases Society of America and the Surgical Infection Society

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Abstract: Despite advances in resuscitation and surgical management of combat wounds, infection remains a concerning and potentially preventable complication of combat-related injuries. Interventions currently used to prevent these infections have not been either clearly defined or subjected to rigorous clinical trials. Current infection prevention measures and wound management practices are derived from retrospective review of wartime experiences, from civilian trauma data, and from in vitro and animal data. This update to the guidelines published in 2008 incorporates evidence that has become available since 2007. These guidelines focus on care provided within hours to days of injury, chiefly within the combat zone, to those combat-injured patients with open wounds or burns. New in this update are a consolidation of antimicrobial agent recommendations to a backbone of high-dose cefazolin with or without metronidazole for most postinjury indications, and recommendations for redosing of antimicrobial agents, for use of negative pressure wound therapy, and for oxygen supplementation in flight.

Key Words: Guidelines, Infection, Combat, Trauma, Prevention.

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EXECUTIVE SUMMARY

Infectious complications of combat trauma have plagued man throughout the ages. Advances in body armor and in the medical care provided from the point-of-injury to definitive care have allowed injured personnel to survive what previously would have been fatal injuries. Personnel surviving these severe injuries, which are often complex and associated with extensive tissue destruction, are at high risk for both early and remote infectious complications. Strategies

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TABLE 1. GRADE* Systematic Weighting of the Quality of Evidence and Grading of Recommendations

Strength of Recommendation and Quality of Evidence		Methodological Quality of Supporting Evidence (Examples)	Clarity of Balance Between Desirable and Undesirable Effects
IA	Strong recommendation, high-quality evidence	Consistent evidence from well-performed RCTs or exceptionally strong evidence from unbiased observational studies	Desirable effects clearly outweigh undesirable effects or vice versa
IB	Strong recommendation, moderate-quality evidence	Evidence from RCTs with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) or exceptionally strong evidence from unbiased observational studies	Desirable effects clearly outweigh undesirable effects or vice versa
IC	Strong recommendation, low-quality evidence	Evidence for at least one critical outcome from observational studies, RCTs with serious flaws or indirect evidence	Desirable effects clearly outweigh undesirable effects or vice versa
ID	Strong recommendation, very low-quality evidence	Evidence for at least one critical outcome from unsystematic clinical observations or very indirect evidence	Desirable effects clearly outweigh undesirable effects or vice versa
IIA	Weak recommendation, high-quality evidence	Consistent evidence from well-performed RCTs or exceptionally strong evidence from unbiased observational studies	Desirable effects closely balanced with undesirable effects
IIB	Weak recommendation, moderate-quality evidence	Evidence from RCTs with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) or exceptionally strong evidence from unbiased observational studies	Desirable effects closely balanced with undesirable effects
IIC	Weak recommendation, low-quality evidence	Evidence for at least one critical outcome from observational studies, from RCTs with serious flaws or indirect evidence	Uncertainty in the estimates of desirable effects, harms, and burden; desirable effects, harms, and burden may be closely balanced
IID	Weak recommendation, very low-quality evidence	Evidence for at least one critical outcome from unsystematic clinical observations or very indirect evidence	Major uncertainty in the estimates of desirable effects, harms, and burden; Desirable effects may or may not be balanced with undesirable effects may be closely balanced

RCTs, randomized controlled trials.
* Grades of Recommendation, Assessment, Development, and Evaluation (GRADE), www.gradeworkinggroup.org.

to prevent these infections are chiefly derived from retrospective review of experiences in past and current conflicts, from civilian trauma data, and from in vitro and animal data. The best clinical practices to prevent infections in combat injuries have not been fully established. The following guidelines integrate available evidence and expert opinion, from the military and civilian medical community, both within and outside of the United States. These updated guidelines provide recommendations to healthcare providers for the management of combat-injured patients with open wounds or burns to prevent infectious complications. They focus on care from point-of-injury until arrival to tertiary care facilities outside of the combat zone. Postinjury antimicrobials, early wound cleansing (irrigation) and surgical debridement, delayed closure, and bony stabilization, with emphasis on maintenance of infection control measures,[1] are the essential components in reducing the incidence of these infections. New in this update are a consolidation of antimicrobial agent recommendations to a backbone of high-dose cefazolin with or without metronidazole for most postinjury indications and recommendations for redosing of antimicrobial agents, for use of negative pressure wound therapy (NPWT), and for oxygen supplementation in flight. Although focused on prevention of infections after injuries produced by combat, these guidelines may be applicable to noncombat traumatic injuries under certain circumstances.

Each section begins with a question and is followed by numbered recommendations from the panel with strength and quality of supporting evidence ratings (Table 1). In addition, a table is included to guide use of these recommendations based on the (US military) level of medical care (Table 2). Recommendations are supported by the five evidence-based reviews included in this *Journal of Trauma* supplement: (1) *Prevention of infections associated with combat-related extremity injuries,*[2] (2) *Prevention of infections associated with combat-related central nervous system injuries,*[3] (3) *Prevention of infections associated with combat-related eye, maxillofacial, and neck injuries,*[4] (4) *Prevention of infections associated with combat-related thoracic and abdominal cavity injuries,*[5] *and* (5) *Prevention of infections associated with combat-related burn injuries.*[6]

RECOMMENDATIONS FOR THE PREVENTION OF INFECTIONS ASSOCIATED WITH COMBAT-RELATED INJURIES

A. Initial Care in the Field

I. What Initial Care/Stabilization Should be Provided to the Injured Patient in the Field Before Evacuation to a Medical Care Facility (Medical Treatment Facilities)?

1. Wounds should be bandaged with sterile dressing and fractures stabilized before transportation to higher level of care (**IB**) (Table 2).
2. Dressing covering the eye should provide protection while avoiding producing pressure on the orbit (**IB**). A Fox shield or other such device should be employed.

TABLE 2. Recommendations to Prevent Infections Associated With Combat-Related Injuries Based on Level of Care

Level of Care*	Care Category	Recommendations
Role 1/Level I (prehospital)	Initial care in the field	-Bandage wounds with sterile dressings (avoid pressure over eye wounds) (**IB**)
		Stabilize fractures (**IB**)
		Transfer to surgical support as soon as feasible (**IB**)
	Postinjury antimicrobials	Provide single-dose point-of-injury antimicrobials (Table 3) if evacuation is delayed or expected to be delayed (**IC**)
Role 1/Level II / Role 2/Level II without surgical support (IIa)	Postinjury antimicrobials	Provide IV antimicrobials (Table 3) as soon as possible (within 3 h) (**IB**)
		Provide tetanus toxoid and immune globulin as appropriate
		Enhance gram-negative coverage with aminoglycoside or fluoroquinolone not recommended (**IB**)
		Addition of penicillin to prevent clostridial gangrene or streptococcal infection is not recommended (**IC**)
		Redose antimicrobials if large volume blood produce resuscitation (**IC**)
		Use only topical antimicrobials for burns (**IB**)
	Debridement and irrigation	Irrigate wounds to remove gross contamination with normal saline, sterile, or potable water, under low pressure (bulb syringe or equivalent) without additives (**IB**)
		Do not attempt to remove retained deep soft tissue fragments if criteria met (**IB**).† Provide cefazolin 2 g IV × 1 dose
Role 2/Level II with surgical support (IIb)/ Role 3/ Level III	Postinjury antimicrobials	Provide IV antimicrobials (Table 3) as soon as possible (within 3 h) (**IB**)
		Provide tetanus toxoid and immune globulin as appropriate
		Enhance gram-negative coverage with aminoglycoside or fluoroquinolone not recommended (**IB**)
		Addition of penicillin to prevent clostridial gangrene or streptococcal infection is not recommended (**IC**)
		Redose antimicrobials if large volume blood produce resuscitation (**IC**)
		Use only topical antimicrobials for burns (**IB**)
		Antimicrobial beads or pouches may be used (**IB**)
		Provide postsplenectomy immunizations if indicated (**IB**)
	Debridement and irrigation	Irrigate wounds to remove contamination with normal saline or sterile water, under low pressure (5–10 PSI, e.g., bulb syringe or gravity flow) without additives (use 3 L for each Type I, 6 L for each Type II, and 9 L for each Type III extremity fractures) (**IB**)
		Do not attempt to remove retained deep soft tissue fragments if criteria met (**IB**).† Provide cefazolin 2 g IV × 1 dose
		Do not obtain cultures unless infection is suspected (**IB**)
	Surgical wound management	Surgical evaluation as soon as possible (**IB**)
		Only dural and facial wounds should undergo primary closure (**IB**)
		NPWT can be used (**IB**)
		External fixation (temporary spanning) of femur/tibia fractures (**IB**)
		External fixation (temporary spanning) or splint immobilization of open humerus/forearm fractures (**IB**)
Role 4/Level IV	Postinjury antimicrobials	Complete course of postinjury antimicrobials (Table 3)
		Antimicrobial beads or pouches may be used (**IB**)
		Provide postsplenectomy immunizations if indicated (**IB**)
	Debridement and irrigation	Irrigate wounds to remove contamination with normal saline or sterile water, under low pressure (5–10 PSI, e.g., bulb syringe or gravity flow) without additives (use 3 L for each Type I, 6 L for each Type II, and 9 L for each Type III extremity fractures) (**IB**)
		Do not attempt to remove retained deep soft tissue fragments if criteria met (**IB**).† Provide cefazolin 2 g IV × 1 dose
		Do not obtain cultures unless infection is suspected (**IB**)
	Surgical wound management	Wounds should not be closed until 3–5 d postinjury (**IB**)
		Only dural and facial wounds should undergo primary closure (**IB**)
		NPWT can be used (**IB**)
		External fixation (temporary spanning) of femur/tibia fractures (**IB**)
		External fixation (temporary spanning) or splint immobilization of open humerus/forearm fractures (**IB**)

IV, intravenous; PSI, pounds per square inch.

* Role of care, level of care, and echelon of care are considered synonymous with role currently the preferred US military term. Definitions of role/level/echelon of care: *Role 1*—self-aid, buddy aid, combat lifesaver, and combat medic/corpsman care at the point-of-injury; physician/physician assistant care at battalion aid station (BAS; US Army) or shock trauma platoon (US Marine Corps [USMC]); no patient holding capacity; *Role 2*—medical company (includes forward support medical company, main support medical company, and area support medical company in US Army) or expeditionary medical support (EMEDS, US Air Force [USAF]); 72 h patient holding capacity, basic blood transfusion, radiography, and laboratory support. May be supplemented with surgical assets (2b) (forward surgical team, US Army; mobile field surgical team, USAF; forward resuscitative surgical system, USMC); *Role 3*—combat support hospital (CSH, US Army), Air Force theater hospital (AFTH, USAF), or casualty receiving ships (USN); full inpatient capacity with intensive care units and operating rooms; *Role 4*—regional hospital (Landstuhl Regional Medical Center, Germany) or USNS hospital ships (USN), typically outside of the combat zone; general and specialized inpatient medical and surgical care; *Role 5*—care facilities within United States, typically tertiary care medical centers.

† Criteria for allowing retained fragments to remain behind: entry/exit wounds < 2 cm; no bone, joint, vascular, and body cavity involvement; no high-risk etiology (e.g., mine); no obvious infection; and assessable by X-ray.

3. Patients should be transferred to a facility with surgical support as soon as feasible (**IB**) (see recommendation 44).
4. Given the unpredictable nature of casualty evacuation in a combat zone, point-of-injury antimicrobial agents (see recommendation 20) should be provided if evacuation is delayed or expected to be delayed (**IC**).

B. Postinjury Antimicrobials

II. Should Systemic Antimicrobials be Given to Patients With Combat-Related Injuries Immediately Postinjury?

5. Systemic antimicrobials should be administered as soon as possible after injury to prevent early infectious complications, including sepsis, caused by common bacterial flora. Ideally, postinjury antimicrobials should be given within 3 hours of injury (**IB**).

III. Which Antimicrobials (and What Dosing Regimens) Should be Employed for Postinjury Use?

6. Antimicrobial selection should focus on providing the narrowest spectrum of activity required, providing coverage of expected common bacterial flora. If multiple injuries are present, the antimicrobial agent selection should be based on the narrowest spectrum needed to cover all wound sites/types (**IB**). Postinjury antimicrobials are provided to prevent early infectious complications, including sepsis. These recommended antimicrobials are not meant to treat established infections where nosocomial pathogens, including multidrug-resistant (MDR), may be the infecting agents (Table 3).
7. Selected agents should be dosed to maximize pharmacokinetics and pharmacodynamics. Logistical considerations, including limiting number of agents to be stocked and maintaining sufficient quantities in the combat zone, should also be considered.

Extremity Wounds

8. Cefazolin, 2 g intravenously (IV) every 6 hours to 8 hours, should be used as the antimicrobial of choice in extremity injuries (skin, soft tissue, and/or bone) (**IB**). Clindamycin may be given as an alternate agent if previous documented anaphylaxis to β-lactam antimicrobials.
9. Enhanced gram-negative coverage should not be employed (**IB**).
10. Addition of penicillin to provide antimicrobial coverage of clostridial gangrene and group A β-hemolytic *Streptococcus* infections is not required (**IC**).

Central Nervous System Wounds

11. Cefazolin, 2 g IV every 6 hours to 8 hours, should be employed for central nervous system (CNS) injuries (**IB**).
12. Add metronidazole, 500 mg IV every 8 hours to 12 hours, if brain grossly contaminated with organic debris (**ID**).
13. Add metronidazole, 500 mg IV every 8 hours to 12 hours, if spinal cord injury associated with concomitant abdominal cavity penetration (**IC**).

Eye, Maxillofacial, and Neck Wounds

14. For penetrating eye injuries, levofloxacin, 500 mg IV or orally every 24 hours, should be provided (**IB**).
15. For maxillofacial and neck injuries, cefazolin, 2 g IV every 6 hours to 8 hours, should be provided (**IC**). Clindamycin, 600 mg IV every 8 hours, may be used as an alternate (**IC**).

Thoracic and Abdominal Cavity Wounds

16. For thoracic cavity injuries without disruption of the esophagus, cefazolin, 2 g IV every 6 hours to 8 hours, should be used (**IIB**).
17. Cefazolin, 2 g IV every 6 hours to 8 hours, with metronidazole, 500 mg IV every 8 hours to 12 hours, should be provided for penetrating wounds to the abdomen and penetrating wounds to the thorax that result in esophageal injury (**IIB**). Alternate regimens include single-dose ertapenem (1 g IV) or moxifloxacin (400 mg IV) (**IIB**).

Burns

18. Topical antimicrobial agents should be used for burn wounds in conjunction with debridement (**IB**). Silver sulfadiazine cream alternating with mafenide acetate cream is preferred. Debridement may not be feasible at lower levels of care; in this situation, clean, dry dressing should be applied to burn wound until the patient is transferred to a higher level of care.
19. Systemic antimicrobials are not indicated for postinjury therapy (**IC**), or for debridement performed as part of routine wound care (**IB**), unless required for concomitant traumatic injuries. Systemic antimicrobials may be considered for perioperative prophylaxis during excision and grafting procedures (**IC**). Cefazolin, 2 g IV every 6 hours to 8 hours for 24 hours, is sufficient for coverage of skin flora. However, antimicrobial agents effective against *Pseudomonas* should be considered if wounds are grossly colonized or older than 5 days.

Point-of-Injury Antimicrobial Selection

20. Point-of-injury antimicrobials as suggested by the Tactical Combat Casualty Care (TCCC) Committee currently include moxifloxacin, 400 mg orally, if casualty does not have penetrating abdominal trauma, is not in shock, and can take oral medications. In patients who do not meet these criteria, single-dose ertapenem (1 g IV or intramuscularly [IM]) or cefotetan (2 g IV or IM) every 12 hours has been suggested. IV therapy is preferred over IM.

Pediatric Considerations

21. Children should be treated with the same antimicrobial agents as those suggested for adults, including those topical antimicrobials suggested for burns. Dosing of antimicrobials in children weighing less than 40 kg should be weight-based. Cefazolin should be dosed at 20 mg/kg to 30 mg/kg IV every 6 hours to 8 hours (up to maximum of 100 mg/kg/d). Metronidazole should be dosed at 30 mg/kg/d IV in four divided doses.

TABLE 3. Postinjury Antimicrobial Agent Selection and Duration Based Upon Injury Pattern*

Injury	Preferred Agent(s)	Alternate Agent(s)	Duration
Extremity wounds (includes skin, soft tissue, and bone)			
Skin, soft tissue, no open fractures	Cefazolin 2 g IV q6–8 h†‡	Clindamycin (300–450 mg PO TID or 600 mg IV q8 h)	1–3 d
Skin, soft tissue, with open fractures, exposed bone, or open joints	Cefazolin 2 g IV q6–8 h†‡§	Clindamycin 600 mg IV q8 h	1–3 d
Thoracic wounds			
Penetrating chest injury without esophageal disruption	Cefazolin 2 g IV q6–8 h†‡	Clindamycin (300–450 mg PO TID or 600 mg IV q8 h)	1 d
Penetrating chest injury with esophageal disruption	Cefazolin 2 g IV q 6–8 h†‡ plus metronidazole 500 mg IV q8–12 h	Ertapenem 1 g IV × 1 dose or moxifloxacin 400 mg IV × 1 dose	1 d after definitive washout
Abdominal wounds			
Penetrating abdominal injury with suspected/known hollow viscus injury and soilage; may apply to rectal/perineal injuries as well	Cefazolin 2 g IV q 6–8 h†‡ plus metronidazole 500 mg IV q8–12 h	Ertapenem 1 g IV × 1 dose or moxifloxacin 400 mg IV × 1 dose	1 d after definitive washout
Maxillofacial and neck wounds			
Open maxillofacial fractures, or maxillofacial fractures with foreign body or fixation device	Cefazolin 2 g IV q6–8 h†‡	Clindamycin 600 mg IV q8 h	1 d
Central nervous system wounds			
Penetrating brain injury	Cefazolin 2 g IV q6–8 h.†‡ Consider adding metronidazole 500 mg IV q8–12 h if gross contamination with organic debris	Ceftriaxone 2 g IV q24 h. Consider adding metronidazole 500 mg IV q8–12 h if gross contamination with organic debris. For penicillin allergic patients, vancomycin 1 g IV q12 h plus ciprofloxacin 400 mg IV q8–12 h	5 d or until CSF leak is closed, whichever is longer
Penetrating spinal cord injury	Cefazolin 2 g IV q6–8 h.†‡ ADD metronidazole 500 mg IV q8–12 h if abdominal cavity is involved	As above. ADD metronidazole 500 mg IV q8–12 h if abdominal cavity is involved	5 d or until CSF leak is closed, whichever is longer
Eye Wounds			
Eye injury, burn or abrasion	Topical: Erythromycin or Bacitracin ophthalmic ointment QID and PRN for symptomatic relief Systemic: No systemic treatment required	Fluoroquinolone 1 drop QID	Until epithelium healed (no fluorescein staining)
Eye injury, penetrating	Levofloxacin 500 mg IV/PO once daily. Before primary repair, no topical agents should be used unless directed by ophthalmology		7 d or until evaluated by a retinal specialist
Burns			
Superficial burns	Topical antimicrobials with twice daily dressing changes (include mafenide acetate‖ or silver sulfadiazine; may alternate between the two), silver-impregnated dressing changed q3–5 d, or Biobrane	Silver nitrate solution applied to dressings	Until healed
Deep partial-thickness burns	Topical antimicrobials with twice daily dressing changes, or silver-impregnated dressing changed q3–5d, plus excision and grafting	Silver nitrate solution applied to dressings plus excision and grafting	Until healed or grafted
Full-thickness burns	Topical antimicrobials with twice daily dressing changes plus excision and grafting	Silver nitrate solution applied to dressings plus excision and grafting	Until healed or grafted

TABLE 3. Postinjury Antimicrobial Agent Selection and Duration Based Upon Injury Pattern* (continued)

Injury	Preferred Agent(s)	Alternate Agent(s)	Duration
Point-of-injury/delayed evacuation¶			
Expected delay to reach surgical care	Moxifloxacin 400 mg PO × 1 dose. Ertapenem 1 g IV or IM if penetrating abdominal injury, shock, or unable to tolerate PO medications	Levofloxacin 500 mg PO × 1 dose. Cefotetan 2 g IV or IM q12 h if penetrating abdominal injury, shock, or unable to tolerate PO medications	Single-dose therapy

IV, intravenous; PO, orally; IM, intramuscularly; TID, three times daily; QID, four times daily; PRN, as needed; CSF, cerebrospinal fluid.

* Postinjury antimicrobial agents are recommended to prevent early posttraumatic infectious complications, including sepsis, secondary to common bacterial flora. Selection is based on narrowest spectrum and duration required to prevent early infections before adequate surgical wound management. This narrow spectrum is selected to avoid selection of resistant bacteria. The antimicrobials listed are not intended for use in established infections, where multidrug-resistant or other nosocomial pathogens may be causing infection.

† Cefazolin may be dosed based on body mass: 1 g if weight ≤80 kg (176 lbs), 2 g if weight 81–160 kg (177–352 lbs), 3 g if weight >160 kg (>352 lbs); doses up to 12 g daily are supported by FDA-approved package insert.

‡ Pediatric dosing: cefazolin, 20–30 mg/kg IV q6–8 h (maximum, 100 mg/kg/d); metronidazole, 7.5 mg/kg IV q6 h; clindamycin 25–40 mg/kg/d IV divided q6–8 h; ertapenem, 15 mg/kg IV or IM q12 h (children up to 12 yr) or 20 mg/kg IV or IM once daily (children over 12 yr; maximum, 1 g/d); ceftriaxone, 100 mg/kg/d IV divided q12–24 h (dosing for CNS injury); levofloxacin, 8 mg/kg IV or PO q12 h (levofloxacin is only FDA-approved in children for prophylaxis of inhalational anthrax in children older than 6 mo, but this dose is commonly used for other indications); vancomycin, 60 mg/kg/d IV divided q6 h (dosing for CNS injury); ciprofloxacin, 10 mg/kg IV (or 10–20 mg/kg PO) q12 h.

§ These guidelines do not advocate adding enhanced gram-negative bacteria coverage (i.e., addition of fluoroquinolone or aminoglycoside antimicrobials) in Type III fractures.

‖ Mafenide acetate is contraindicated in infants younger than 2 mo.

¶ Postinjury antimicrobial therapy as suggested by the Tactical Combat Casualty Care Committee.

IV. What Duration of Antimicrobials Should be Given to Patients After Combat-Related Injuries?

22. The shortest course of postinjury antimicrobial therapy should be used (**IB**) (Table 3). If multiple wounds are present, the duration of antimicrobials is dictated by the injury pattern requiring the longest duration of therapy. Duration should not be extended for open wounds, drains, or external fixation devices. Wounds should be continually reassessed for evidence of infection and antimicrobials directed specifically at known or empirically suspected infecting pathogens provided if infection is suspected or proven.

Extremity Wounds

23. Antimicrobials should be provided for 1 day to 3 days for all extremity wounds (**IB**).

CNS Wounds

24. Antimicrobials are recommended for 5 days or until cerebrospinal fluid (CSF) leak is closed, whichever time period is longer (**ID**).

Eye, Maxillofacial, and Neck Wounds

25. For penetrating eye injuries, antimicrobials should be provided for a total of 7 days or until a thorough evaluation by a retinal specialist with adequate capabilities has been performed (**IC**).
26. For maxillofacial and neck injuries, 1 day of antimicrobial coverage should be provided (**IC**).

Thoracic and Abdominal Cavity Wounds

27. Thoracic injuries with esophageal injury should also receive a total of 1 day of antimicrobials after definitive operative washout (**IB**).
28. Casualties should receive a total of 1 day of antimicrobials after definitive operative washout for abdominal cavity injuries (**IB**).

Burns

29. Topical antimicrobial agents should be used for burns until wounds are successfully covered with healed skin, whether spontaneously or following successful skin grafting (**IC**).

V. Should Antimicrobials be Redosed Before Next Schedule Dosing Interval if Patients Require Substantial Blood Product Support, Require Large Volume Resuscitation, or Have Severe Acidosis?

30. Redosing of antimicrobials should be performed after large volume blood product resuscitation (1,500–2,000 mL of blood loss) has been completed, regardless of when the last dose of antimicrobial was administered (**IC**).

VI. Should Local Delivery of Antimicrobials Through Topical Application or Beads (Bead Pouches) be Implemented in the Care of Combat-Related Injuries?

31. Local delivery of topical antimicrobials may be provided for extremity infections in the form of antimicrobial beads or pouches as long as the emphasis is still on surgical debridement and irrigation (**IB**).
32. Local delivery of other antimicrobials (other than in burn care), to include powders or soaking of wet to dry dressing with antimicrobials, should not be used routinely (**IB**).

VII. What Vaccines or Other Immunotherapy Should be Provided Postinjury?

Tetanus Toxoid or Immune Globulin

33. Patients who have been previously immunized against tetanus (received 3 or more doses of toxoid) do not require booster dose of vaccine unless it has been more than 5 years since their last dose. They do not require tetanus immune globulin (TIG) (**IB**).
34. Unimmunized patients, and those with unknown vaccination status, should receive TIG and vaccine (with additional doses of vaccine given at 4 weeks and 6 months) postinjury (**IC**).
35. Early surgical debridement and irrigation in addition to postinjury antimicrobials and vaccine may be effective in the prevention of tetanus in the absence of TIG administration (**IID**).

Postsplenectomy Immunization

36. Patients who have had their spleens removed should receive immunization against *Streptococcus pneumoniae*, *Neisseria meningitidis*, and *Hemophilus influenza* serotype B (**IB**). Immunization should be provided within 14 days of splenectomy.

C. Debridement and Irrigation

VIII. When Should Irrigation Fluid be Implemented in the Management of Combat-Related Injuries?

37. Wound irrigation should be initiated as soon as clinically possible by appropriately trained personnel (**ID**).

IX. Should Additives Supplement Irrigation Fluid for Combat-Related Injuries?

38. Additives should not be included in standard irrigation fluid as normal saline (or alternately, sterile water or potable water) is adequate (**IB**).

X. What Volume of Fluid Should be Used to Irrigate Wounds Associated With Combat Injuries?

39. Sufficient volume to remove debris should be employed (**IB**). For extremity injuries, standard volumes of 3 L, 6 L, and 9 L should be provided for type I, II, and III fractures, respectively; however, larger volumes might be required for more severe injuries (**IB**).

XI. What Pressure Should be Used to Deliver Irrigation in the Management of Combat-Related Injuries?

40. Irrigation fluid should be delivered at low pressure (5–10 PSI [pounds per square inch] may be delivered by bulb syringe or gravity irrigation) (**IB**).

XII. Should Pre- and/or Postdebridement Bacterial Culture of Combat-Related Wounds be Performed?

41. Clinicians should obtain bacterial cultures only when there are concerns for an ongoing wound infection based upon systemic signs or symptoms of infection, local appearance of wounds, and laboratory or radiographic imaging studies (**IB**).
42. Results from infection control surveillance cultures should not be used for initiation of therapy (**IC**).

XIII. Can Retained Soft Tissue Fragments Remain in a Combat-Related Injury Wound?

43. Casualties with isolated retained deep extremity soft tissue metal fragments meeting certain clinical and radiographic criteria should be treated with a single dose of cefazolin, 2 g IV, without fragment removal (**IB**). Patients should be monitored for evidence of subsequent infection.

D. Surgical Wound Management

XIV. When Should Patients With Combat-Related Injuries Undergo Initial Surgical Management?

44. Patients should be evacuated to surgical care as soon as possible based upon a risk-benefit analysis of the combat environment (**IB**).
45. Penetrating injuries of the eye (**IB**) and spine without neurologic compromise (**IC**) should await surgical debridement until appropriate surgical expertise is available.
46. Foreign material embedded in the brain, which are not readily accessible, should not be removed by non-neurosurgeons (**IB**).
47. All burn injuries should undergo thorough cleansing and debridement, estimation of extent and depth, and coverage with appropriate topical antimicrobial agents within 8 hours of injury (**IC**). Early (within 5 days) excision and grafting is suggested for deep partial-thickness and full-thickness burns (**IA**). This should ideally be performed outside of the combat zone by surgeons with appropriate training and experience.

XV. When Should Combat-Related Wounds be Closed?

48. Wounds, to include open fractures, should not be closed early; typical closure should be performed 3 days to 5 days after injury if there is no evidence of infection (**IB**).

49. For injuries that involve the face or dura, primary closure should be performed (**IB**).
50. For abdominal and thoracic injuries, the skin should not be closed if there is a colon injury or extensive devitalized tissue due to excessive infectious complications (**IB**).
51. Early primary repair of complex or destructive colonic injuries should not be performed especially if associated with massive blood transfusion, ongoing hypotension, hypoxia, reperfusion injury, multiple other injuries, high-velocity injury, or extensive local tissue damage (**IB**).
52. If the abdomen is left open, the possibility of partial or complete closure should be considered at each subsequent laparotomy (**IB**).
53. Scheduled laparotomies should be performed in this group at 24-hour to 48-hour intervals (**IB**).

XVI. Should External Fixation be Standard for Stabilization of Fracture?

54. Temporary spanning external fixation should be placed for femoral and tibial fractures (**IB**). Use of external fixation in the current conflicts allows stabilization during long evacuations to the United States, easy observation of wounds (over use of plaster), and potentially less chronic infections (over early open reduction and internal fixation).
55. Temporary spanning external fixation or splint immobilization placement with transition to open plate and screw osteosynthesis should be employed for open humerus and forearm fractures after soft tissue stabilization (**IB**).

XVII. Can NPWT be Used in the Management of Combat-Related Wounds?

56. NPWT should be used in the management of open wounds (excluding CNS injuries) to include during aeromedical evacuation of patients (**IB**).
57. Use of intermittent suction or instillation of normal saline in conjunction with NPWT is discouraged in most situations based upon preliminary animal studies (**ID**).
58. Local delivery of antimicrobials using beads or pouches might be effective in combination with NPWT and could be considered (**IID**).

XVIII. Should Supplemental Oxygen be Provided During Transportation of the Wounded to Medical Facilities Outside the Combat Zone?

59. During aeromedical evacuation, supplemental oxygen (to maintain oxygen saturation >92%) may be beneficial in patients with combat-related injuries (**IIC**).

E. Facility Infection Control and Prevention

XIX. What Infection Control and Prevention Measures Should be Implemented in Deployed Medical Treatment Facilities?

60. Basic infection control and prevention measures should be employed at all deployed medical treatment facilities (MTF). These should include hand hygiene, with compliance monitoring. Infection control and prevention should include MTF Commander oversight and emphasis (**IB**).
61. Transmission-based (isolation) precautions should be implemented (**IB**).
62. Cohorting (i.e., physically separating patients expected to be hospitalized for less than 72 hours from those expected to be hospitalized longer) should be used (**IC**).
63. An infection control officer should be assigned to each deployed MTF that provides inpatient care. This officer should have adequate training and experience to lead the infection control program at the MTF.
64. All deployed MTF should practice antimicrobial stewardship (**IC**). Clinical microbiology assets are crucial to antimicrobial stewardship and should be available at MTF which hospitalize patients for more than 72 hours.

INTRODUCTION

Battlefield trauma management emphasizes early delivery of medical care that includes hemorrhage control, hypotensive and hemostatic resuscitation, and administration of antimicrobial therapy with a goal to minimize excess morbidity and mortality.[7–10] Historically, infections have been major complications of combat-related injuries, with an infection rate of 3.9% among 17,726 wounded in the Vietnam War. This rate significantly underestimates the true burden of infection because only data from care provided within the combat zone and during the first 7 days after injury were included.[11] Sepsis, or likely multisystem organ failure, was the third leading overall cause of death and the most common cause of death for those casualties who survived the first 24 hours after injury.[12,13] Studies from the current wars in Iraq and Afghanistan have similarly reported that in those who do die of their wounds, a high incidence die from sepsis or multisystem organ failure secondary to infection.[14,15]

Wounds incurred during combat have resulted in infectious complications to include sepsis and death. These complications continue to be common among recent combat casualties, including those secondary to MDR bacteria such as *Acinetobacter baumannii-calcoaceticus* complex, *Pseudomonas aeruginosa*, methicillin-resistant *Staphylococcus aureus*, and extended-spectrum β-lactamase-producing organisms such as *Escherichia coli* and *Klebsiella pneumoniae*.[16–19] Severe injuries and admission to an intensive care unit have been shown to be associated with higher infection rates during the current conflicts in Iraq and Afghanistan.[16,20] Gram-negative bacteria infect and colonize casualties in the period immediately after injury, whereas gram-positive bacteria infect and colonize patients during the rehabilitative period.[17–19] Increasing colonization with MDR bacteria throughout the evacuation chain from the combat zone, through Germany, to the United States supports the concept that most MDR bacteria colonization and infection is healthcare-associated.[21–24] The nosocomial spread of MDR bacterial infections throughout the evacuation chain also supports the need for limiting the overuse of broad spectrum antimicrobial agents and emphasizes the need for compliance with infection control measures.

The primary injury patterns associated with combat-related injuries is extremity damage, with increasing rates of maxillofacial and neck injuries and relatively stable number of burn patients during the wars in Iraq and Afghanistan.[25–33] Infection rates have been noted to be ~15% to 25% in the current wars in Iraq and Afghanistan with substantial associated morbidity and mortality.[16,17,34] This rate reaches more than 40% in those wounded who require intensive care unit admission.[35] The goals of combat-related injury care include preventing infection, promoting healing, and restoring function. The *Guidelines for the Prevention of Infection after Combat-Related Injuries* published in 2008 and supporting evidence-based reviews focused on initial stabilization, systemic antimicrobial therapy, wound debridement and irrigation, timely wound closure, and appropriate follow-up.[36–41]

In these guidelines, the previous evidence-based recommendations are updated, using military and civilian data to optimally minimize infections after combat-related trauma. Efforts were made to ensure that these recommendations could be applied across all levels of medical care in a combat zone and could be modified based on the equipment and medical expertise available at each care level. Finally, where necessary, management strategies consider differing evacuation times and the management of personnel not evacuated out of the combat zone (such as local nationals). The utility of antimicrobial agents, debridement and irrigation, surgical wound management, and facility infection control and prevention is emphasized.

PRACTICE GUIDELINES

Practice guidelines are systematically developed statements to assist practitioners and patients in making decisions about appropriate health care for specific clinical circumstances. Attributes of good guidelines include validity, reliability, reproducibility, clinical applicability, clinical flexibility, clarity, multidisciplinary process, review of evidence, and documentation.

METHODOLOGY

Panel Composition

A panel of experts composed of infectious disease (D.R.H., C.K.M., N.G.C., L.C.D., M.A.F., A.D.G., K.E.K., G.J.M., K.P., D.E.S., D.R.T., T.J.W., G.W.W.); surgical specialists, including general surgery/trauma/critical care (G.P.C., W.C.D., J.R.D., B.J.E., J.B.H., J.S.S.), orthopedic surgery (R.C.A., J.H.C., J.C.C., J.R.F., M.E.F., J.R.H., W.T.O.), cardiothoracic surgery (J.M.C.), vascular surgery (T.K.C.), neurosurgery (L.E.M.), ophthalmology (M.H.C.), oral maxillofacial surgery (R.B.B., R.G.H.), otolaryngology (D.K.H.), and burns (L.C.C., E.M.R., J.R.S.); infection control (H.K.C.); preventive medicine (A.R.W.); critical care (K.K.C.); and translational research (J.C.W.) was assembled. US military officers (D.R.H., C.K.M., R.C.A., L.C.C., J.M.C., K.K.C., M.H.C., N.G.C., G.P.C., H.K.C., T.K.C., L.C.D., W.C.D., J.R.D., B.J.E., J.R.F., M.E.F., M.A.F., R.G.H., D.K.H., J.R.H., K.E.K., G.J.M., L.E.M., K.P., E.M.R., D.E.S., T.J.W., A.R.W., G.W.W.), civilian experts (R.B.B., J.H.C., W.T.O., J.R.S., J.S.S., D.R.T., J.C.W.), and two British military medical officers (J.C.C., A.D.G.) were included on the panel. Essentially, all military personnel had experience in Afghanistan and/or Iraq and in caring for casualties from these conflicts outside of the combat zone.

Literature Review and Analysis

Review of the medical literature was performed initially by members of the five review teams based on body system or type of injury. These included teams focused on extremity injuries, CNS injuries, eye, maxillofacial, and neck injuries, thoracic and abdominal cavity injuries, and burn injuries. Literature reviews were performed by searching PubMed for all English language publications relevant to the material of interest from January 2007 through December 2010. All abstracts were reviewed and full-length articles relevant to the subject were pulled for further review of references to be included in literature review and analysis. All articles were then reviewed for populations under study including war-related or civilian trauma, type of study design, and size of study. Focus was on human studies, but key animal studies were included where human data were limited or unavailable. Unpublished research performed by members of the panel was also considered in these recommendations.

Process Overview

In evaluating the evidence regarding the prevention of infections associated with combat-related injury, the panel followed a process used in the development of Infectious Diseases Society of America (IDSA) guidelines. The process included a systematic weighting of the quality of the evidence and the grading of the recommendations using the Grades of Recommendation, Assessment, Development, and Evaluation (GRADE; www.gradeworkinggroup.org) system (Table 1). The first priority was to evaluate articles on military trauma. To supplement this, civilian trauma articles, primarily randomized control trials and then cohort studies, were reviewed. An attempt was made to assign a level to denote both the strength of recommendations and quality of the evidence available to support those recommendations.

Consensus Development Based on Evidence

The review teams evaluated summary documents of key articles and preliminary drafts of their manuscripts in electronic format. Clarification of the quality of evidence and recommendations to present to the entire panel were addressed during these processes. The entire panel met to finalize recommendations and assessments of quality of evidence for the guidelines. All panel members participated in the preparation of the draft guidelines. The contents of the guidelines and the manuscript were reviewed and endorsed by the IDSA Standards and Practice Guideline Committee, the IDSA Board of Directors, and the Executive Council of the Surgical Infection Society before dissemination.

Guidelines and Conflict of Interest

All panel members complied with the IDSA policy on conflicts of interest, which requires disclosure of any financial or other interest that might be construed as constituting an actual, potential, or apparent conflict. Members of the

panel were provided IDSA's conflict of interest disclosure statement and were asked to identify ties to companies developing products that might be affected by promulgation of the guideline. Information was requested regarding employment, consultancies, stock ownership, honoraria, research funding, expert testimony, and membership on company advisory committees. The panel made decisions on a case-by-case basis as to whether an individual's role should be limited as a result of a conflict. No limiting conflicts were identified.

Summary of Outcomes Assessed

The information derived from the literature is limited as there are no prospective randomized clinical trials in or out of the combat zone dealing with injuries from the ongoing conflicts in Iraq and Afghanistan for the various clinical questions. Therefore, the data are summarized by military relevant data and then by presenting civilian injury trauma and general trauma studies. Generalizing civilian trauma care data to that of combat trauma care may not be valid because of differences in mechanisms of injury, energy transferred to tissue, time to initial assessment and care, diagnostic capabilities at initial receiving facilities and the austere nature of many of those facilities, and access to and type of medical care systems available. Efforts were also made to ensure that these recommendations could be applied across the different levels of medical care in a combat zone and could be modified based on the equipment and medical expertise available at each level. Finally, management strategies had to incorporate possible differing evacuation times, and the management of personnel not evacuated out of the combat zone.

RECOMMENDATIONS FOR THE PREVENTION OF INFECTIONS ASSOCIATED WITH COMBAT-RELATED INJURIES

A. Initial Care in the Field

I. What Initial Care/Stabilization Should be Provided to the Injured Patient in the Field Before Evacuation to a Medical Care Facility (Medical Treatment Facilities)?

1. Wounds should be bandaged with sterile dressing and fractures stabilized before transportation to higher level of care (**IB**) (Table 2).
2. Dressing covering the eye should provide protection while avoiding producing pressure on the orbit (**IB**). A Fox shield or other such device should be employed.
3. Patients should be transferred to a facility with surgical support as soon as feasible (**IB**) (see recommendation 44).
4. Given the unpredictable nature of casualty evacuation in a combat zone, point-of-injury antimicrobial agents (see recommendation 20) should be provided if evacuation is delayed or expected to be delayed (**IC**).

Evidence Summary

Open wounds should be protected by bandaging with sterile dressings applied to prevent further contamination. Fractures should be splinted to prevent further tissue damage before transporting patients to higher levels of care.[8–10,42] Eye injuries should be protected in a fashion which does not produce pressure on the eye, because pressure placed on an open globe may cause suprachoroidal hemorrhage and irreversible blindness.[43] Use of a Fox shield or improvised field expedient eye cover has been suggested. Dressings applied to open cranial and spinal injuries should provide protection while avoiding producing pressure on the exposed brain or spinal cord. Discussion of the evidence to support recommendations 3 and 4 is included in the evidence summaries for recommendations 44 and 5, respectively.

B. Postinjury Antimicrobials

II. Should Systemic Antimicrobials be Given to Patients With Combat-Related Injuries Immediately Postinjury?

5. Systemic antimicrobials should be administered as soon as possible after injury to prevent early infectious complications, including sepsis, caused by common bacterial flora. Ideally, postinjury antimicrobials should be given within 3 hours of injury (**IB**).

Evidence Summary

Data from previous and current conflicts support early delivery of antimicrobial agents.[44–47] Although studies among civilian trauma patients do not consistently support earlier delivery of antimicrobial agents, they are supported by various guidelines.[48–53] In addition, animal studies support the premise that earlier antimicrobials can delay the onset of infection and are beneficial.[54–60]

III. Which Antimicrobials (and What Dosing Regimens) Should be Employed for Postinjury Use?

6. Antimicrobial selection should focus on providing the narrowest spectrum of activity required, providing coverage of expected common bacterial flora. If multiple injuries are present, the antimicrobial agent selection should be based on the narrowest spectrum needed to cover all wound sites/types (**IB**). Postinjury antimicrobials are provided to prevent early infectious complications, including sepsis. These recommended antimicrobials are not meant to treat established infections where nosocomial pathogens, including MDR, may be the infecting agents (Table 3).
7. Selected agents should be dosed to maximize pharmacokinetics and pharmacodynamics. Logistical considerations, including limiting number of agents to be stocked and maintaining sufficient quantities in the combat zone, should also be considered.

Extremity Wounds

8. Cefazolin, 2 g IV every 6 hours to 8 hours, should be used as the antimicrobial of choice in extremity injuries (skin, soft tissue, and/or bone) (**IB**). Clindamycin may be given as an alternate agent if previous documented anaphylaxis to β-lactam antimicrobials.

9. Enhanced gram-negative coverage should not be employed (**IB**).
10. Addition of penicillin to provide antimicrobial coverage of clostridial gangrene and group A β-hemolytic *Streptococcus* infections is not required (**IC**).

CNS Wounds

11. Cefazolin, 2 g IV every 6 hours to 8 hours, should be employed for CNS injuries (**IB**).
12. Add metronidazole, 500 mg IV every 8 hours to 12 hours, if brain grossly contaminated with organic debris (**ID**).
13. Add metronidazole, 500 mg IV every 8 hours to 12 hours, if spinal cord injury associated with concomitant abdominal cavity penetration (**IC**).

Eye, Maxillofacial, and Neck Wounds

14. For penetrating eye injuries, levofloxacin, 500 mg IV or orally every 24 hours, should be provided (**IB**).
15. For maxillofacial and neck injuries, cefazolin, 2 g IV every 6 hours to 8 hours, should be provided (**IC**). Clindamycin, 600 mg IV every 8 hours, may be used as an alternate (**IC**).

Thoracic and Abdominal Cavity Wounds

16. For thoracic cavity injuries without disruption of the esophagus, cefazolin, 2 g IV every 6 hours to 8 hours, should be used (**IIB**).
17. Cefazolin, 2 g IV every 6 hours to 8 hours, with metronidazole, 500 mg IV every 8 hours to 12 hours, should be provided for penetrating wounds to the abdomen and penetrating wounds to the thorax that result in esophageal injury (**IIB**). Alternate regimens include single-dose ertapenem (1 g IV) or moxifloxacin (400 mg IV) (**IIB**).

Burns

18. Topical antimicrobial agents should be used for burn wounds in conjunction with debridement (**IB**). Silver sulfadiazine cream alternating with mafenide acetate cream is preferred. Debridement may not be feasible at lower levels of care; in this situation, clean, dry dressing should be applied to burn wound until the patient is transferred to a higher level of care.
19. Systemic antimicrobials are not indicated for postinjury therapy (**IC**), or for debridement performed as part of routine wound care (**IB**), unless required for concomitant traumatic injuries. Systemic antimicrobials may be considered for perioperative prophylaxis during excision and grafting procedures (**IC**). Cefazolin, 2 g IV every 6 hours to 8 hours for 24 hours, is sufficient for coverage of skin flora. However, antimicrobial agents effective against *Pseudomonas* should be considered if wounds are grossly colonized or older than 5 days.

Point-of-Injury Antimicrobial Selection

20. Point-of-injury antimicrobials as suggested by the TCCC Committee currently include moxifloxacin, 400 mg orally, if casualty does not have penetrating abdominal trauma, is not in shock, and can take oral medications. In patients who do not meet these criteria, single-dose ertapenem (1 g IV or IM) or cefotetan (2 g IV or IM) every 12 hours has been suggested. IV therapy is preferred over IM.

Pediatric Considerations

21. Children should be treated with the same antimicrobial agents as those suggested for adults, including those topical antimicrobials suggested for burns. Dosing of antimicrobials in children weighing less than 40 kg should be weight-based. Cefazolin should be dosed at 20 mg/kg to 30 mg/kg IV every 6 hours to 8 hours (up to maximum of 100 mg/kg/d). Metronidazole should be dosed at 30 mg/kg/d IV in four divided doses.

Evidence Summary

The antimicrobials of choice were selected to maximize pharmacokinetics and pharmacodynamics for patients with multiple injuries while minimizing the number of agents needed to be stocked and employed in the combat zone. In addition, focus was placed on recommending antimicrobial agents with the most limited spectrum needed for postinjury use to avoid driving the selection of MDR bacteria. Overall, the agents selected should include coverage of all injury types that a particular patient has. Use of high-dose cefazolin is based on pharmacokinetic studies of dosing based on patient weight.[61–63] Dosing of metronidazole at intervals more than every 8 hours is also supported by recent data.[64] In addition to the management of coalition and local adult patients, host-nation pediatric patients constitute a large percentage of those receiving care in the combat hospitals with infections being a common complication.[65–68]

Extremity Wounds

Postinjury antimicrobial agent selection is primarily based on retrospective studies and expert opinion, with data typically focused on more severe extremity injuries, notably type III fractures.[48–50,69–74] Of wounds not needing surgical evacuation in a combat zone, a single study revealed the overall importance of wound irrigation over systemic antimicrobials.[75] High-dose cefazolin was selected in this guideline because of concerns of underdosing wounded personnel who weigh more than 70 kg and low serum concentrations of drug with blood loss.[76] The package insert indicates that up to 12 g/d of cefazolin has been used.[61,62,77] A recommendation against adding enhanced gram-negative coverage was based on the lack of clear data documenting the benefit of this practice and concerns that adding a fluoroquinolone or aminoglycoside might increase selection of subsequent nosocomial MDR pathogens. In addition, no single aminoglycoside has been identified that could potentially cover all the MDR bacteria currently being recovered subsequently in the care of combat casualties, and all these agents carry the concern for potential renal toxicity in under-resuscitated patients who might sustain hypovolemic renal injury.[78–81] Clindamycin was selected as an alternative therapy based upon controlled trials revealing efficacy, especially in type I and II fractures.[74,82]

The incidence of gas gangrene and streptococcal infections after injury has remained exceedingly low during the

prolonged conflicts in Afghanistan and Iraq. This is likely secondary to aggressive surgical management with delayed primary closure of wounds. In addition, both *Clostridium perfringens* and *Streptococcus pyogenes* are likely covered with the antimicrobials currently provided after combat-related injuries, and thus the addition of penicillin should not be given.[48,69,70,83–89]

CNS Wounds

Several recent review articles have summarized data from civilian and military traumatic casualties resulting in penetrating brain injury and have recommended the use of postinjury antimicrobials for the prevention of infection.[90,91] The data supporting these recommendations are based on retrospective reviews and expert opinion and do not support a standard treatment regimen or duration. For penetrating injuries to the spine, multiple reports have shown a 0% to 32% infectious complication rate and varied postinjury antimicrobial usage.[92–98]

Eye, Maxillofacial, and Neck Wounds

Given the excellent pharmacokinetics and effective spectrum of coverage of the newer fluoroquinolone agents, administration of systemic levofloxacin or moxifloxacin should be sufficient to prevent endophthalmitis after traumatic (penetrating) eye injury.[99–101] Retrospective review has demonstrated low rates of endophthalmitis with use of these agents.[102]

Antimicrobial therapy with ampicillin, penicillin, and cephalosporins has been used effectively in maxillofacial and neck combat injuries, but the organisms causing infection, dosing, duration of therapy, and definition of infection are poorly described.[103,104] However, randomized controlled trials of antimicrobial prophylaxis of infection for contaminated head and neck surgery (nontrauma patients) show a 77% to 79% reduction in infection compared with placebo.[105,106] Therefore, postinjury antimicrobial therapy of the contaminated injuries of combat trauma is recommended. Recommended agents are based on data from the same nontrauma population and include high-dose cefazolin, 2 g IV every 6 hours to 8 hours.[107] This higher dose is preferred as lower doses did not seem to be as effective.[108] Alternate use of clindamycin (600 mg IV every 8 hours) is also supported by the noncombat trauma literature.[109,110]

Thoracic and Abdominal Cavity Wounds

Postinjury antimicrobial selection for thoracic and abdominal cavity trauma is based on trauma data from the civilian community.[111–115] Use of ertapenem is based on its perioperative use in elective colorectal surgery.[116] Moxifloxacin has been demonstrated to have comparable efficacy to combination therapies in recent studies of complicated intra-abdominal infections.[117–120]

Burns

Topical antimicrobial therapy is currently the standard in postburn care.[121] Systemic antimicrobial agents are not recommended for debridement performed as part of routine wound care but have been used for perioperative prophylaxis during excision and grafting procedures, especially in patients with larger burns, although the data for this practice are inconclusive. Early studies documented a significant incidence of transient bacteremia associated with wound manipulation,[122] but a more recent evaluation showed this incidence to be much reduced.[123] Antimicrobial administration has been found to reduce the incidence of this transient bacteremia but did not affect outcomes.[124] A recently published study by Ramos et al.[125] found that the use of systemic perioperative antimicrobial administration for patients undergoing grafting of deep burns was associated with improved autograft survival. However, the study had several limitations, including a small sample size, and a more extensive follow-up study will be required. Because of the limited evidence, controversy on this topic exists, and burn units vary widely in their practices of providing perioperative antimicrobial prophylaxis.[126,127] Although the data are inconclusive, the clinician may consider the use of perioperative systemic antimicrobials for excision and grafting procedures.

Point-of-Injury Antimicrobial Selection

A panel of military trauma experts on point-of-injury care (TCCC Committee) have recommended oral moxifloxacin and intravenous/intramuscular cefotetan or ertapenem as point-of-injury antimicrobials.[8–10,128] Selection of point-of-injury field antimicrobials is based on three criteria: (1) activity against the expected infecting pathogens for the body part injured, (2) stability in the field environment, and (3) ease of delivery (dosing interval and volume of infusion) on the battlefield with minimal adverse events.[9,10,128,129] A recent study evaluating point-of-injury antimicrobials by US Army Rangers did not seem to show clear infection prevention benefit, although the numbers were small. Of note, no increases in colonization or infection with MDR bacteria were noted, nor were medication toxicities reported. There are clear arguments for choosing agents with much narrower antibacterial spectrums of activity; however, it seems the antimicrobials recommended by the TCCC Committee are not causing harm and may be beneficial. TCCC recommendations include use of IV or IM ertapenem or cefotetan for point-of-injury antimicrobials in those wounded unable to take oral agents.[8–10] Although TCCC Committee has also made recommendations for the use of the intraosseous (IO) delivery route for fluid and analgesic therapy, IO delivery of antimicrobials has not been systematically studied in military populations or trauma patients.[130,131] In animal studies, those antimicrobials that are highly protein bound were associated with lower serum concentrations with IO delivery compared with IV delivery.[132] Both cefazolin and ertapenem are highly protein bound antimicrobials. Although IM delivery has also not been studied in military or trauma patient populations, both cefazolin and ertapenem are approved by the Food and Drug Administration for use by this route.

Pediatric Considerations

Pediatric trauma is a common occurrence in the combat theater, and children are frequently cared for in deployed medical settings. The appropriate choices of antimicrobial agents for the prevention of trauma-related infection in children are essentially identical to those for adults. Accurate

weight-based dosing of these drugs is critical as the pharmacokinetics of these medications in the young child often results in higher dose-per-weight and more frequent dosing requirements. In general, adult dosing of antimicrobials should be used in children weighing 40 kg or more, as weight-based dosing about this can result in doses exceeding the maximum adult dosage. Neonates younger than 28 days, or those weighing less than 2 kg, have significantly different metabolism and clearance of most antimicrobials, and different regimens should be used.

The doses of the most commonly used antimicrobial agents include cefazolin (20–30 mg/kg IV every 6–8 hour, up to a maximum dose of 100 mg/kg/d) and metronidazole (30 mg/kg/d IV, divided into 4 daily doses). Ertapenem has been approved for use in children older than 3 months; however, once daily dosing is inadequate. The recommended dose is 15 mg/kg IV or IM every 12 hours for children through 12 years (for children older than 12 years, the dose is 20 mg/kg once daily, with a maximum dose of 1 g).

Although limited data are available on the safety and dosage of moxifloxacin in children, ciprofloxacin is a well-studied and safe option in pediatric. Ciprofloxacin (10 mg/kg IV every 12 hours) or levofloxacin (8 mg/kg IV every 12 hours) in combination with metronidazole is a reasonable choice for postinjury therapy of penetrating abdominal injuries in children. Pediatric dosing for other antimicrobials recommended in these guidelines include clindamycin 25 mg/kg/d to 40 mg/kg/d IV divided into 6- to 8-hour dosing. Antimicrobial dosing of the alternate agents for CNS trauma includes vancomycin 60 mg/kg/d divided into 6- to 8-hour dosing and ceftriaxone 100 mg/kg/d IV given in every 12 hours or once daily.

The use of topical antimicrobials in pediatric burns is similar to that used in adults, with the exception that mafenide acetate should be avoided in neonates because of the risk of kernicterus association with sulfonamides.

IV. What Duration of Antimicrobials Should be Given to Patients After Combat-Related Injuries?

22. The shortest course of postinjury antimicrobial therapy should be used (**IB**) (Table 3). If multiple wounds are present, the duration of antimicrobials is dictated by the injury pattern requiring the longest duration of therapy. Duration should not be extended for open wounds, drains, or external fixation devices. Wounds should be continually reassessed for evidence of infection and antimicrobials directed specifically at known or empirically suspected infecting pathogens provided if infection is suspected or proven.

Extremity Wounds

23. Antimicrobials should be provided for 1 day to 3 days for all extremity wounds (**IB**).

CNS Wounds

24. Antimicrobials are recommended for 5 days or until CSF leak is closed, whichever time period is longer (**ID**).

Eye, Maxillofacial, and Neck Wounds

25. For penetrating eye injuries, antimicrobials should be provided for a total of 7 days or until a thorough evaluation by a retinal specialist with adequate capabilities has been performed (**IC**).
26. For maxillofacial and neck injuries, 1 day of antimicrobial coverage should be provided (**IC**).

Thoracic and Abdominal Cavity Wounds

27. Thoracic injuries with esophageal injury should also receive a total of 1 day of antimicrobials after definitive operative washout (**IB**).
28. Casualties should receive a total of 1 day of antimicrobials after definitive operative washout for abdominal cavity injuries (**IB**).

Burns

29. Topical antimicrobial agents should be used for burns until wounds are successfully covered with healed skin, whether spontaneously or following successful skin grafting (**IC**).

Evidence Summary

Based upon the civilian trauma literature, existing military and civilian guidelines, and the high prevalence of (presumed nosocomial) MDR bacterial infections being reported among casualties from Iraq and Afghanistan and the risk of prolonged antimicrobial therapy in increasing rates of nosocomial infections, short courses of postinjury antimicrobial therapy should be used.

Extremity Wounds

Postinjury antimicrobial therapy should be given for at least 24 hours. Civilian data focused on severe (type III) extremity fractures support continuing therapy for 1 day to 3 days with reassessment of wounds. Antimicrobial agents should only be continued for ongoing infection and then directed at the bacteria's specific resistance profile instead of the prevention focus of initial antimicrobials.[50,52,69,70,133–137]

CNS Wounds

There are no controlled trials identifying the optimal duration of postinjury antimicrobial therapy. A previous review has recommended 5 days for penetrating craniocerebral injury with retained organic material.[90] For penetrating injuries of the spine, one review suggested antimicrobial use for a minimum of 48 hours with extension to 7 days if the alimentary tract was violated.[94] A recent review of traumatic brain and spinal cord injury from the current conflicts in Iraq and Afghanistan revealed baseline rates of meningitis consistent with previous wars but noted a three times higher incidence of meningitis in patients with CSF leaks.[138] Based on the available literature, antimicrobial therapy should be continued for 5 days or until CSF leak control has occurred. With ventriculostomy placement, it is common practice by many neurosurgeons to continue postinjury antimicrobials until final removal of these devices. Data to support or discourage this practice are not currently available.

Eye, Maxillofacial, or Neck Wounds

No studies in combat ocular trauma patients have been performed to define duration of postinjury antimicrobial therapy. Traumatic endophthalmitis is generally a rapid-onset, fulminant process that creates substantial ocular morbidity.[139] Treatment in these cases generally requires a combination of intravitreal antimicrobials and vitrectomy surgery.[140] Because vitreoretinal capabilities are not available or advised until casualties reach tertiary care outside the combat zone, it is recommended that systemic antimicrobial therapy continues until the patient arrives where surgical management would be possible in the event of endophthalmitis. In the event of delayed evacuation, no less than a 7-day course of treatment is recommended.[102]

No studies in combat trauma victims exist to best define duration of therapy in maxillofacial or neck injury. However, both recent and previous studies of mandibular fractures and contaminated head and neck cases with similar outcomes have all concluded antimicrobial therapy in excess of 24 hours perioperatively do not seem to reduce wound infections.[141–146] Thus, postinjury antimicrobial therapy should be discontinued 24 hours postoperatively.

Thoracic and Abdominal Cavity Wounds

With prompt surgical management, postinjury antimicrobial therapy can be limited to 1 day in thoracic and abdominal cavity injuries.[111,147,148]

Burns

There are no existing studies that define the optimal duration of topical antimicrobial therapy for burn wounds. It is common practice at the US Army Institute of Surgical Research burn center for topical antimicrobial agents to be used until wounds are successfully covered with healed skin, whether by spontaneous healing or after successful skin grafting.

V. Should Antimicrobials be Redosed Before Next Schedule Dosing Interval if Patients Require Substantial Blood Product Support, Require Large Volume Resuscitation, or Have Severe Acidosis?

30. Redosing of antimicrobials should be performed after large volume blood product resuscitation (1,500–2,000 mL of blood loss) has been completed, regardless of when the last dose of antimicrobial was administered (**IC**).

Evidence Summary

Large volume resuscitation with IV fluids and blood products may result in hemodilution of postinjury antimicrobial therapy. Redosing of antimicrobial agents after large volume resuscitation or blood loss (estimated at 1,500–2,000 mL of blood loss) is supported by the civilian medical literature.[63,149–152]

VI. Should Local Delivery of Antimicrobials Through Topical Application or Beads (Bead Pouches) be Implemented in the Care of Combat-Related Injuries?

31. Local delivery of topical antimicrobials may be provided for extremity infections in the form of antimicrobial beads or pouches as long as the emphasis is still on surgical debridement and irrigation (**IB**).
32. Local delivery of other antimicrobials (other than in burn care), to include powders or soaking of wet to dry dressing with antimicrobials, should not be used routinely (**IB**).

Evidence Summary

Local delivery of topical antimicrobials has been used in the surgical treatment of bony and orthopedic device-related infections for several decades. Use of local wound therapy in the form of antimicrobial beads or pouches is used adjunctively and is not a substitute for good surgical debridement and irrigation. Local antimicrobial beads may be used even if NPWT is used. However, data do not support the local delivery of other antimicrobials to include powder or soaking of wet to dry dressing with antimicrobials.[153–169] Direct application of antimicrobials to the brain or spinal cord is contraindicated in the absence of the ability to monitor serum and spinal fluid antimicrobial levels.

VII. What Vaccines or Other Immunotherapy Should be Provided Postinjury?

Tetanus Toxoid or Immune Globulin

33. Patients who have been previously immunized against tetanus (received 3 or more doses of toxoid) do not require booster dose of vaccine unless it has been more than 5 years since their last dose. They do not require TIG (**IB**).
34. Unimmunized patients, and those with unknown vaccination status, should receive TIG and vaccine (with additional doses of vaccine given at 4 weeks and 6 months) postinjury (**IC**).
35. Early surgical debridement and irrigation, in addition to postinjury antimicrobials and vaccine may be effective in the prevention of tetanus in the absence of TIG administration (**IID**).

Postsplenectomy Immunization

36. Patients who have had their spleens removed should receive immunization against *Streptococcus pneumoniae*, *Neisseria meningitidis*, and *Hemophilus influenza* serotype B (**IB**). Immunization should be provided within 14 days of splenectomy.

Evidence Summary

Provision of tetanus immunotherapy to prevent infections in contaminated wounds has been the standard of care for decades. Treatment with vaccine or immune globulin is based on whether patient has previously received adequate immunization (3 or more doses of tetanus toxoid). However, the only cases seen to date within the combat zone have been in Afghan and Pakistani civilians managed in military hospitals after the 2005 Pakistan earthquakes. These cases presented days after their traumatic injuries. In the past several years, a shortage of TIG has resulted in numerous patients being managed without TIG immune therapy. That tetanus

has not been reported in this group has been postulated to be due to the effectiveness of early wound care and postinjury antimicrobials (personal communication, Dr. Andrew Green).

Spleen removal places patients at risk for overwhelming postsplenectomy sepsis from encapsulated bacteria, especially *Streptococcus pneumoniae*. Because of this risk, immunization with pneumococcal vaccine has been provided, as has meningococcal and *Hemophilus* vaccine, albeit at a lower rate. Ideal timing of immunization postsplenectomy is not clear, although two studies of immunologic response to vaccine in this setting support giving vaccine at 14 days post removal.[170,171] Immunization with pneumococcal (and other vaccines) vaccine has typically given by trauma surgeons from immediately postoperatively to up to 6 weeks.[172]

C. Debridement and Irrigation

VIII. When Should Irrigation Fluid be Implemented in the Management of Combat-Related Injuries?

37. Wound irrigation should be initiated as soon as clinically possible by appropriately trained personnel (**ID**).

Evidence Summary

Wound irrigation should be initiated as soon as clinically possible by appropriately trained personnel based upon a small military study and animal data.[75,173]

IX. Should Additives Supplement Irrigation Fluid for Combat-Related Injuries?

38. Additives should not be included in standard irrigation fluid as normal saline (or alternately, sterile water or potable water) is adequate (**IB**).

Evidence Summary

Additives should not be included in standard irrigation fluid as normal saline (including sterile water or potable water) is adequate, and additives often are associated with increased tissue damage and subsequent bacterial rebound in the wounds of animal studies.[133,174–180] A large clinical trial looking at irrigant additives for extremity injuries is underway which might modify this recommendation in the future.[175]

X. What Volume of Fluid Should be Used to Irrigate Wounds Associated With Combat Injuries?

39. Sufficient volume to remove debris should be employed (**IB**). For extremity injuries, standard volumes of 3 L, 6 L, and 9 L should be provided for type I, II, and III fractures, respectively; however, larger volumes might be required for more severe injuries (**IB**).

Evidence Summary

The volume of fluid sufficient to fully irrigate most wounds is unknown. Standard volumes of 3 L, 6 L, and 9 L have been suggested and promoted for irrigation of type I, II, and III fractures, respectively.[174,180] However, as the size of wounds varies, even among these defined categories, selection of irrigant volume must be based on that required for the adequate decontamination of any unique wound.

XI. What Pressure Should be Used to Deliver Irrigation in the Management of Combat-Related Injuries?

40. Irrigation fluid should be delivered at low pressure (5–10 PSI, may be delivered by bulb syringe or gravity irrigation) (**IB**).

Evidence Summary

Irrigation fluid pressure should be low pressure (5–10 PSI) as higher pressure irrigation likely damages tissue and possibly push contamination further into wound, resulting in rebound increase in bacterial contamination at 24 hours to 48 hours.[133,175] It is anticipated that the FLOW (Fluid Lavage of Open Wounds) multicenter, randomized trial will clarify the role of low versus high pressure in extremity injuries.[175]

XII. Should Pre- and/or Postdebridement Bacterial Culture of Combat-Related Wounds be Performed?

41. Clinicians should obtain bacterial cultures only when there are concerns for an ongoing wound infection based upon systemic signs or symptoms of infection, local appearance of wounds, and laboratory or radiographic imaging studies (**IB**).
42. Results from infection control surveillance cultures should not be used for initiation of therapy (**IC**).

Evidence Summary

Routine sampling of clinically uninfected wounds is not supported as a method to select postinjury or empirical antimicrobial therapy. Clinicians should obtain bacterial cultures only when there are concerns for an ongoing wound infection based upon systemic signs or symptoms of infection, local appearance of wound, and laboratory or radiographic imaging studies.[17–19,46,48,70,181–198] Infection control surveillance cultures should not be used for initiation of therapy as that would expose patients to unnecessary antimicrobials with potential excess toxicity and selection for MDR bacteria.

XIII. Can Retained Soft Tissue Fragments Remain in a Combat-Related Injury Wound?

43. Casualties with isolated retained deep extremity soft tissue metal fragments meeting certain clinical and radiographic criteria should be treated with a single dose of cefazolin, 2 g IV, without fragment removal (**IB**). Patients should be monitored for evidence of subsequent infection.

Evidence Summary

Combat injuries often result in retained fragments of metallic or other materials within the soft tissues which are too deep or too numerous to easily remove without the

removal procedure itself creating further morbidity. In the absence of infection or concerns of complications (based on location), it is not necessary to remove all of these foreign bodies. Criteria for observation of small retained fragments include X-ray confirmation revealing no bone involvement, no vascular involvement, and no break of pleura or peritoneum, wound entry/exit lesions less than 2 cm in maximal dimension, and no signs of infection.[199–213] Although previous studies have used 5 days of therapy, response to single-dose therapy has been described in the current conflicts and is likely adequate based upon civilian extremity management.

D. Surgical Wound Management

XIV. When Should Patients With Combat-Related Injuries Undergo Initial Surgical management?

44. Patients should be evacuated to surgical care as soon as possible based upon a risk-benefit analysis of the combat environment (**IB**).
45. Penetrating injuries of the eye (**IB**) and spine without neurologic compromise (**IC**) should await surgical debridement until appropriate surgical expertise is available.
46. Foreign material embedded in the brain, which are not readily accessible, should not be removed by non-neurosurgeons (**IB**).
47. All burn injuries should undergo thorough cleansing and debridement, estimation of extent and depth, and coverage with appropriate topical antimicrobial agents within 8 hours of injury (**IC**). Early (within 5 days) excision and grafting is suggested for deep partial-thickness and full-thickness burns (**IA**). This should ideally be performed outside of the combat zone by surgeons with appropriate training and experience.

Evidence Summary

Patients should be evacuated to surgical care as soon as possible based upon a thorough risk benefit analysis of the combat environment.[11,44,46,50,51,70,87,135,186–189,197,214–223] An interesting study of high-energy lower extremity trauma indicated that care at a definitive trauma center was vital.[53] Eye and spine injuries without neurologic compromise should await surgical debridement until appropriate surgical expertise is available; cerebral foreign bodies should remain if removal would cause excess damage.[224–230]

Extremity Wounds

Data assessing outcomes based on time to procedures are limited for combat casualties, although most of the data indicate delayed interventions are associated with increased infection.[44,46,215,231] Civilian guidelines recommend that rapid surgical debridement is the primary treatment and antimicrobials are adjuvant therapy for infection prophylaxis in open fracture management.[49,133,216] The civilian literature, however, is mixed on the benefit of early surgical intervention.[50,51,218–223] A recent study of 315 severe high-energy extremity injuries revealed that time to debridement was not associated with infection (<5 hours, 28% infected [93 patients]; 5–10 hours, 29.1% infected [86 patients]; >10 hours, 25.8% infected [128 patients]).[53] Interestingly this study indicated that time to a definitive trauma center was the most important factor on decreasing infection rate.

CNS Wounds

Historically, extensive debridement of retained material had been recommended for penetrating brain injury; however, recent reviews have shown improved preservation of brain function with less aggressive surgical debridement.[224–230] Thus, current management is to remove only easily accessible foreign material and grossly devitalized tissue. In penetrating spinal injuries, retained bullets have not been shown to be a significant risk factor for infectious complications unless the injury is associated with gross contamination or a tract exists from the peritoneal cavity to the spinal canal.[94] In the latter instances, exploration and low pressure irrigation of the wound are recommended. In patients with declining neurologic function, early removal of bone fragments or foreign bodies causing compression of neurologic structures is recommended to prevent further neurologic compromise.

Eye, Maxillofacial, and Neck Wounds

Rapid evacuation and treatment of the maxillofacial and neck wounds, to include the use of antimicrobials resulted in a decrease in mortality from 40% in World War II to 1.3% during the Korean War.[232,233] One factor attributed to the low incidence of endophthalmitis during the current conflicts has been the early primary closure of open globes (within 6 hours).[102] Given the low rate of infection, the current treatment paradigm is recommended.

Thoracic and Abdominal Cavity Wounds

Thoracic injuries requiring tube thoracostomy will, in many combat related cases, require urgent placement in the field. In one study in a civilian trauma setting, prehospital thoracostomy performed by a physician at the accident scene was determined to be safe but had only a nonsignificant decrement in infected hemothoraces.[234] Placement by more experienced providers was associated with fewer complications in another series.[235] Reevaluation and early evacuation of residual clot should be performed to minimize development of infected hematoma and empyema.[236]

Prompt surgical intervention has been the standard in combat wounds to the abdomen since World War I. Regarding closure of the skin, a number of series of civilian abdominal and colonic injuries, associated with fewer high-velocity penetrating injuries, primary skin closure has been advocated with good success.[237,238]

Controversy in abdominal trauma currently revolves around the timing of closure of the abdominal fascia. Severely injured, combat or noncombat-related abdominal injuries have improved outcomes with "damage control surgery" consisting of an immediate abbreviated laparotomy with goals of hemostasis, limitation of contamination through closure or resection of bowel perforations, delayed bowel anastomoses or ostomies, and wound packing, all in an effort to provide rapid restoration of physiologic parameters. Delayed closure and use of vacuum pack technique with subsequent definitive surgery is recommended.[239–245]

Burns

Early burn excision, within 5 days of injury, seems to improve survival in patients without inhalation injuries.[246–248]

XV. When Should Combat-Related Wounds be Closed?

48. Wounds, to include open fractures, should not be closed early; typical closure should be performed 3 days to 5 days after injury if there is no evidence of infection (**IB**).
49. For injuries that involve the face or dura, primary closure should be performed (**IB**).
50. For abdominal and thoracic injuries, the skin should not be closed if there is a colon injury or extensive devitalized tissue due to excessive infectious complications (**IB**).
51. Early primary repair of complex or destructive colonic injuries should not be performed especially if associated with massive blood transfusion, ongoing hypotension, hypoxia, reperfusion injury, multiple other injuries, high-velocity injury, or extensive local tissue damage (**IB**).
52. If the abdomen is left open, the possibility of partial or complete closure should be considered at each subsequent laparotomy (**IB**).
53. Scheduled laparotomies should be performed in this group at 24- to 48-hour intervals (**IB**).

Evidence Summary

Extremity Wounds

Based upon historical war wound management, early closure of open fracture wounds should not be performed and closure should not be performed until 3 days to 5 days after injury.[174,249–253] Definitive bone coverage should performed as soon as feasible after definitive stabilization.[46,254]

CNS Wounds

It is important to close the injury site as quickly as possible, but with penetrating CNS trauma there is often inadequate dura available. An autologous vascularized pericranial tissue graft or commercially available dural substitute can be used successfully in these instances. Cranialization of any violated sinuses and watertight dural and skin closure should follow adequate debridement. In patients who have undergone aggressive cranial decompression after severe blunt or penetrating head injury, the removed bone flap should be discarded if the patient will ultimately be evacuated to a location where custom prosthetic implants are available.[255] Where prosthetic implants are not available (e.g., for nonevacuated local nationals), removed skull fragments should be thoroughly washed and then either replaced or inserted into the abdominal wall fat as a temporary storage location. If the deployed location has a -70°C freezer, this is another option for storage.

Eye, Maxillofacial, and Neck Wounds

For injuries that involve the face, primary closure should be performed.[256]

Thoracic and Abdominal Cavity Wounds

For abdominal injuries, skin should not be closed if there is a colon injury or extensive devitalized tissue due to excessive infectious complications. Early primary repair of complex or destructive colonic injuries should not be performed especially if associated with massive blood transfusion, ongoing hypotension, hypoxia, reperfusion injury, multiple other injuries, high-velocity injury, or extensive local tissue damage.[239,241,257]

XVI. Should External Fixation be Standard for Stabilization of Fracture?

54. Temporary spanning external fixation should be placed for femoral and tibial fractures (**IB**). Use of external fixation in the current conflicts allows stabilization during long evacuations to the United States, easy observation of wounds (over use of plaster), and potentially less chronic infections (over early open reduction and internal fixation).
55. Temporary spanning external fixation or splint immobilization placement with transition to open plate and screw osteosynthesis should be employed for open humerus and forearm fractures after soft tissue stabilization (**IB**).

Evidence Summary

Staged fixation in combat injuries has emerged as the strategy of choice in this conflict.[37] Temporary external fixation has been commonly used as a bridge to definitive fixation with few significant complications.[258] Although a few selected cases of low-energy injuries have been safely internally fixed in the combat zone, it is still considered "ill-advised" in combat-related injuries.[258,259] The use of plaster splints has been recommended and might be useful with rapid evacuations to more definitive orthopedic expertise.[46,231,260]

XVII. Can NPWT be Used in the Management of Combat-Related Wounds?

56. NPWT should be used in the management of open wounds (excluding CNS injuries) to include during aeromedical evacuation of patients (**IB**).
57. Use of intermittent suction or instillation of normal saline in conjunction with NPWT is discouraged in most situations based upon preliminary animal studies (**ID**).
58. Local delivery of antimicrobials using beads or pouches might be effective in combination with NPWT and could be considered (**IID**).

Evidence Summary

NPWT is effective in the management of open wounds (excluding CNS injuries) to include during aeromedical evacuation of patients out of the combat zone. Battery power may be a limitation to its use on longer transports (>8–10 hours).[25,163,174,254,261–266] Intermittent suction or instillation therapy of normal saline should not be implemented based upon preliminary animal studies because of concern for tissue damage (personal communication, Dr. Joseph Wenke). In severe injuries that cannot undergo adequate surgical debridement (e.g., extensive high bilateral lower extremity injuries with perineum involvement secondary to explosive trauma), where the possible risk of local tissue damage from antiseptics is outweighed by preventing or controlling infection,

anecdotal success with topical antiseptics (e.g., Dakin's) in conjunction with NPWT has been reported (personal communication, Dr. Romney Andersen).

XVIII. Should Supplemental Oxygen be Provided During Transportation of the Wounded to Medical Facilities Outside the Combat Zone?

59. During aeromedical evacuation, supplemental oxygen (to maintain oxygen saturation > 92%) may be beneficial in patients with combat-related injuries (**IIC**).

Evidence Summary

The role of oxygen as therapy has been evaluated and pursued in previous wars especially in association with gas gangrene.[267–270] More recently, there has been an ongoing concern regarding low oxygenation level in patients with wounds that occur with long-distance air evacuation from the combat zone to Germany and from Germany to the United States. Preliminary animal studies show decreased bacterial burden when hypoxia is treated with supplemental oxygen to maintain an oxygen saturation of more than 93% (personal communication, Dr. Warren Dorlac). In addition, prospective (civilian, nontrauma) studies have shown mixed results of the use of oxygen supplementation in preventing postsurgical infectious after abdominal and pelvic surgeries, although these studies were not associated with hypoxia induced by elevation.[271–273]

E. Facility Infection Control and Prevention

XIX. What Infection Control and Prevention Measures Should be Implemented in Deployed Medical Treatment Facilities?

60. Basic infection control and prevention measures should be employed at all deployed MTF. These should include hand hygiene, with compliance monitoring. Infection control and prevention should include MTF Commander oversight and emphasis (**IB**).
61. Transmission-based (isolation) precautions should be implemented (*IB*).
62. Cohorting (i.e., physically separating patients expected to be hospitalized for less than 72 hours from those expected to be hospitalized longer) should be used (**IC**).
63. An infection control officer should be assigned to each deployed MTF that provides inpatient care. This officer should have adequate training and experience to lead the infection control program at the MTF.
64. All deployed MTF should practice antimicrobial stewardship (**IC**). Clinical microbiology assets are crucial to antimicrobial stewardship and should be available at MTF which hospitalize patients for more than 72 hours.

Evidence Summary

Infection control and prevention has developed as critical practice to prevent or decrease healthcare-associated infections in MTF. National (civilian) guidelines have been developed by the Centers for Disease Control and Prevention and by other national professional organizations (e.g., IDSA; Society for Healthcare Epidemiology of America [SHEA]; and Association for Professionals in Infection Control and Epidemiology [APIC]). Following the consensus conference to develop our initial guidelines (i.e., *Guidelines for the Prevention of Infection after Combat-Related Injuries*),[38] a review of the deployed MTF in Iraq, Afghanistan, and Kuwait was conducted to assess infection control and prevention challenges and practice in the combat zone.[274] This review led to recommendations for improvement and development of a short course for infection control officers who were to be assigned to a deployed MTF.[274–276]

RESEARCH GAPS

Most of the recommendations included in these guidelines are based on civilian trauma clinical research, retrospective review of combat trauma interventions and outcome, animal research and expert opinion. Research to better answer each of the 19 questions posed in these guidelines is needed. Research gaps include but are not limited to:

- Identifying the best timing of initiation of postinjury antimicrobial therapy.
- Establishing the shortest effective duration needed for postinjury antimicrobial therapy.
- Identifying the best postinjury antimicrobial agents.
- Further evaluation of topical wound therapies, including irrigants.
- Evaluating the role of topical decolonization/cleansing to prevent MDR infections.

In addition, other areas of research could potentially impact efforts to prevent infections in the combat-injured population. These include research into the ecology of wounds (microbiome and biofilm development), the pathophysiology and host immune response associated with when and if infections develop, and development of new diagnostic, prevention, and treatment technologies and strategies. Ongoing epidemiology is also vital to quickly identify changing wounding and infection patterns and the emergence of new etiologic agents.

A better understanding of the wound microbiome and its natural evolution in both injuries which do and do not get infected could better guide care and improve outcomes. Understanding the development and role biofilms play in both acute and chronic wounds and how these interact with the host's immune response could also guide diagnostic and targeted treatment strategies. Diagnostic testing advances in conjunction with enhanced knowledge of the wound microbiome, biofilms, and immune response could identify which patients need antimicrobial therapy, whether this could be local or systemic, and when a wound might be successfully closed. The diagnostic use of inflammatory markers and cytokines is currently being examined as a tool to identify when wounds can be closed without further infectious complications.[277–282]

Invasive fungal infections have recently emerged as an important infectious complication of severe combat injury. Based upon data to date, patients with large bilateral lower extremity injuries typically in lush vegetative areas on dis-

mounted patrol requiring large volume blood product support have been noted to have increased reports of fungal infections, which is consistent with some farm trauma studies.[82,283–285] However at this time, there are inadequate data to determine the role empiric antifungal therapy or tissue characterization techniques with culture or histology. Research is urgently needed to better define the risk factors associated with these infections and to identify potential interventions to prevent this life-threatening complication of combat-related injuries.

PERFORMANCE MEASURES

Performance measures are often used with guidelines to measure effectiveness or benefits of their recommendations. These can include measures of adherence or outcome. Performance measures that may be useful in the prevention of infection associated with combat-related injury include:

- Use of a recommended antimicrobial versus other antimicrobial or combination of antimicrobials for postinjury therapy.
- Time from injury to delivery of postinjury antimicrobials.
- Change in rates of colonization with MDR bacteria at admission to tertiary care medical facilities outside the combat zone.
- Change in rates of infection with MDR bacteria during care at tertiary care medical facilities outside the combat zone.

Admission screening for colonization with MDR has been established at the major US military medical centers receiving wounded from the combat zone. This screening was standardized in 2008 to allow comparison among facilities.[286] Monitoring the change in rates of colonization of combat-injured personnel at admission will in part allow assessment of the benefit of these guidelines.

In addition, the Joint Theater Trauma System, which has a performance improvement project which gathers data to inform medical leaders about wounding patterns, effectiveness of interventions, and emerging trends. The Joint Theater Trauma Registry has recently added an infectious disease module which will allow assessment of the effectiveness of the recommendations in this guideline and provide data for future refinements/updates.

The Department of Defense-Veterans Administration Trauma Infectious Disease Outcomes Study is an observational cohort of infectious disease outcomes after deployment-related traumatic injury in active duty personnel or Department of Defense beneficiary from their initial arrival from the combat theater to posthospitalization follow-up. Trauma history and infectious disease-specific inpatient care information is captured through the Joint Theater Trauma Registry. Assessment of postinjury antimicrobial prescribing practices has already been implemented to monitor adoption of the current guidelines. Outcomes analysis of infectious complications in addition to infection rates secondary to MDR bacteria will also be accomplished through this study.

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