Guidelines for the Prevention of Infection After Combat-Related Injuries

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Management of combat-related trauma is derived from skills and data collected in past conflicts and civilian trauma, and from information and experience obtained during ongoing conflicts. The best methods to prevent infections associated with injuries observed in military combat are not fully established. Current methods to prevent infections in these types of injuries are derived primarily from controlled trials of elective surgery and civilian trauma as well as retrospective studies of civilian and military trauma interventions. The following guidelines integrate available evidence and expert opinion, from within and outside of the US military medical community, to provide guidance to US military health care providers (deployed and in permanent medical treatment facilities) in the diagnosis, treatment, and prevention of infections in those individuals wounded in combat. These guidelines may be applicable to noncombat traumatic injuries under certain circumstances. Early wound cleansing and surgical debridement, antibiotics, bony stabilization, and maintenance of infection control measures are the essential components to diminish or prevent these infections. Future research should be directed at ideal treatment strategies for prevention of combat-related injury infections, including investigation of unique infection control techniques, more rapid diagnostic strategies for infection, and better defining the role of antimicrobial agents, including the appropriate spectrum of activity and duration.

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

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Infections have complicated the care provided to those wounded in war throughout recorded history.[1–3] In addition to the protection afforded by personal body armor, there have been numerous advances in the care provided to combat casualties. These include enhancement in the training and expertise of combat medics, enabling life saving care to be provided at the point of injury, and the rapid evacuation of casualties to surgical care that is provided in close proximity to the point of injury. These advances have enabled personnel to survive near catastrophic injuries; however, they have also placed a greater demand on the healthcare infrastructure by increasing the numbers of patients needing optimal functional rehabilitation and long-term care.

The patterns of injury sustained in combat are predominately extremity injuries (~65%), followed by head and neck (~15%), thorax (~10%), and abdomen (~7%) injuries; burns complicate approximately 5% to 10% of all combat casualties (Table 1[3–11]). Infectious risks associated with these injuries include those from initial wound contamination and from nosocomial infections associated with long-term care. The latter often involving multiply drug resistant-bacteria (multidrug-resistant organisms, MDROs), as has been seen in the current US military conflicts.[12–17]

GUIDELINE DEVELOPMENT

Our committee was established to evaluate the current military and civilian literature and to provide recommendations for a clinical pathway to manage combat casualties using the best available medical evidence. The committee

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Table 1 **Historical Overview of Injury Patterns, Mechanisms of Injury, Time to Presentation, Died of Wounds Rates, and Infection Rates**

	World War I	World War II	Korean War	Vietnam War	Gulf War	Somalia	OIF/OEF
Injury site (%)							
Extremity	70	58–75	67	61–74	56–65	75	54
Head and neck	17	4	17	14	11	14	16
Thorax and abdomen	6	12	14	12	6–15	11	N/A
Mechanism of injury (%)							
Explosive devices	—	—	—	—	—	—	36
Bullet	—	33	—	30	5–20	42	16
Mortar	—	39	—	19	—	—	9
Artillery	—	11	—	3	—	—	8
Grenade, including rocket-propelled (RPG)	—	13	—	23	—	—	16
Land mine/booby trap	—	2	—	17	—	—	2
Fragments*	—	—	—	—	63–95	43	—
Time to evacuation (h)	12–18	10	4–6	1 h—31% 4 h—86%	0.67† 4.41‡	Up to 14	1–2
Died of wounds (%)	8 (of 153,000 wounded)	4.5 (of 599,724 wounded)	2.5 (of 77,788 wounded)	3.6 (of 96,811 wounded)	2.1 (of 143 wounded)	6.4 (of 62 wounded)	—
Wound infection rate (%)	—	—	—	4	—	19	—

* Somalia and Gulf War study grouped all mechanisms into bullets, fragments, or other.

† Before the ground war.

‡ During the ground war.

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members consisted of military and civilian experts in infectious disease, trauma, preventive medicine, infection control, and surgical specialties including general surgery, critical care, orthopedic surgery, neurosurgery, oral maxillofacial surgery, otolaryngology, and burn surgery. Physicians included personnel recently deployed to Iraq and Afghanistan as well as several with military medical experience in the Vietnam conflict. Clinical experience ranged from caring for combat casualties at the point of injury and throughout the evacuation chain, including initial field stabilization, initial surgical stabilization, and care in the combat zone, at US military hospitals in Germany and in the United States.

Five teams reviewed the military and civilian trauma literature before the guideline conference to draft recommendations for the treatment of casualties based on the available evidence. At the conference, sponsored by the United States Army Office of the Surgeon General and hosted by the United States Army Institute of Surgical Research at Fort Sam Houston, Texas, on June 11 to 12, 2007, all participants discussed the presented data and draft guidelines. The medical literature and current surgical practices were reviewed by these five subgroups according to anatomic site or type of injury: extremity, central nervous system (CNS), thoracic and abdominal cavity, head and neck, and burns. Experts involved in the development of the guidelines were asked to review the literature and develop recommendations for the reduction or prevention of infections in combat-related injuries. The first priority was to evaluate military trauma-related articles with an emphasis on well-conducted randomized control trials or cohort studies that could be incorporated into the guidelines. In addition, civilian trauma articles, primarily randomized control trials and then cohort studies, were evaluated. 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. The Infectious Diseases Society of America/US Public Health Service rating system was utilized (Table 2). Limitations in using any rating system were noted early in this review process. For our guidelines, these included the fact that randomized controlled trials have not been performed in combat zones and that generalizing civilian trauma care data to combat trauma care may not be valid because of the differences in mechanisms of injury, time to access, diagnostic capabilities at initial receiving facilities and the austere nature of many of those facilities, and access to and type of medical care systems.

Efforts also were made to ensure that these recommendations could be applied across all 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. After the guidelines were summarized, they were again disseminated to all participants for discussion. Additional discussion of the data supporting specific recommendations is provided in the reviews (by anatomic site/type of injury) within this *Journal of Trauma* supplement.

Table 2 Strength of Recommendation Based on Quality of Evidence Rating System

Strength of Recommendation		Quality of Evidence	
Category	Definition	Grade	Definition
A	Good evidence to support a recommendation for use	I	Evidence from at least one properly randomized controlled trial (RCT)
B	Moderate evidence to support a recommendation for use		
C	Poor evidence to support a recommendation for or against use	II	Evidence from at least one well-designed clinical trial without randomization or from cohort or case-controlled studies
D	Moderate evidence to support a recommendation against use		
E	Good evidence to support a recommendation against use	III	Expert opinion

Adapted from the IDSA/USPHS rating system.

Current Situation

The management of combat casualties within a combat zone and throughout the evacuation chain from point of injury to definitive rehabilitative care in the United States is a complex system. Casualties are managed by numerous physicians at varying levels of medical care in and out of the combat zone. These injured patients may pass through as many as five medical treatment facilities from the time of injury to their return to the United States, spending only a few days at each facility.[12,18] The average evacuation time has been 7 days from injury to arrival in the United States.[12,18] This results in numerous hand-offs, fragmentation of care, and loss of continuity. A particular example of this related to infection is the fact that culture results are available only after the casualty has been evacuated. Additionally, medical personnel assigned to care for combat-related trauma have varying clinical trauma experience and training before arrival in the combat zone. Deployments range from as short as 3 to 4 months for Air Force and Army Reservist physicians to 15 or more months for Army medical personnel (typically 6 months for surgeons) resulting in varying levels of experience and sometimes conflicting management strategies.

Combat casualties are often colonized or infected with MDROs, likely because of nosocomial transmission in and out of the combat zone.[14–16,18,19] Few antimicrobial agents reliably cover these pathogens, necessitating rigorous antibiotic stewardship and infection control strategies to minimize their impact on the health of the injured.

At this time, the only summary of treatment strategies for managing combat casualties is the *Emergency War Surgery* textbook. Unfortunately, it is limited by summary statements without evidence-based recommendations and does not incorporate many of the lessons learned from current conflicts.[6] By reviewing and summarizing the best current evidence and expert opinion, we hope to reduce practice variation inside and outside of the combat zone to further optimize care for injured personnel. It is expected that these guidelines will need to be updated periodically to incorporate advances in trauma management and to ensure the recommendations are appropriate for future combat environments and medical evacuation systems.

Target Patient Population

The pool of potential patients in the combat zone includes both military (United States and coalition) and civilian (US Government, foreign contractor, and indigenous) personnel. The patterns of trauma associated with combat include all anatomic regions and are most commonly the result of either explosive devices with associated fragmentation injuries or gun shot wounds.[5,20–22] Military trauma patients are more likely to have multiple causes for their injuries; that is, they may present with a combination of blunt and penetrating trauma, often with burns and occasionally blast overpressure injuries. US military casualties are predominately young men without comorbid illnesses.[5] In contrast, the civilian victims of combat zone trauma more frequently have comorbidities such as hypertension and diabetes that complicate wound care.[23] A distinct management difference between these two populations is the rapid evacuation of US casualties out of the combat zone. Although there are some drawbacks to the rapid evacuation policy, it allows for long-term definitive care and prolonged follow-up to begin in the United States quickly, often within several days of injury. Civilian personnel managed in the combat zone often receive initial damage control operations and care with one primary team of physicians. Although long-term follow-up is not provided, transfer of civilian patients to local facilities is often delayed until the patient is stabilized, often requiring days in US military intensive care units.

Target Provider Audience

The target audience is all healthcare providers rendering care to patients with combat-related injuries in the combat zone as well as military and civilian medical professionals caring for returning casualties. Recommendations are focused on initial care provided in the combat zone at Levels I through III (see article entitled "Epidemiology of Infections

Related to Combat Injuries in Iraq and Afghanistan" in this supplement for definitions). Care provided at Level IV and V is discussed in the reviews that follow by anatomic site/type of injury (also in this *Journal of Trauma* Supplement).

Scope of These Guidelines

Management strategies for the care of combat casualties begin with the control of hemorrhage and definitive control of the airway and breathing using the concepts of Tactical Combat Casualty Care (TCCC).[24] The primary method to prevent the development of infection in penetrating trauma is rapid surgical evaluation and management. Treatment strategies vary by anatomic location; however, overall treatment strategies include an emphasis on irrigation, debridement, antimicrobial therapy, coverage of wounds, and stabilization of underlying bony structures.

Numerous strategies proposed to modify the rate of surgical site infections, including minimizing blood transfusion, controlling hyperglycemia, minimizing hypothermia, and providing adequate oxygenation will not be addressed in this guideline. These guidelines also do not address the treatment of nosocomial infections associated with war trauma. All treatment facilities should establish and regularly update local antibiograms to direct empiric antimicrobial therapy for nosocomial infections. Timely microbiology support with susceptibility testing should be available to allow rapid de-escalation to directed short-course antimicrobial monotherapy, when possible. The role of an effective infection control program in modifying the risk of nosocomial transmission, especially of multidrug-resistant bacteria, cannot be overemphasized (Table 3). Although institution of infection control procedures in the combat zone is challenging, certain key infection control methods can be readily implemented; these include institution of hand hygiene compliance, proper use of gloves, patient cohorting, appropriate isolation (contact, droplet, airborne), standard protocols for disinfection or sterilization of patient care equipment in a war setting, and appropriate environmental cleaning.[18,25] Antibiotic control programs should be put in place in the combat zone to limit use of broad-spectrum antimicrobial agents. These methods have been shown to be attainable and effective in the combat zone.[25] Finally, although these guidelines are designed to be applicable to various combat environments, many of the recommendations herein are based upon the current conflicts in Iraq and Afghanistan.

Table 3 Infection Control Techniques to Reduce Nosocomial Transmission of Multidrug-Resistant Organisms (MDROs)

Standard precautions
Hand hygiene—always perform before and after each patient contact (whether gloves are worn or not)
Gloves—when contact with nonintact skin or body fluids is anticipated
Gowns—when changing dressings on open wounds
Masks and eye protection—based on anticipated or potential exposure
Contact precautions*
Gloves and gowns—with all patient care
Cohorting
Separation of long-term (>72 h) and short-term (≤72 h) admissions should be considered
Antibiotic control
Avoid unnecessary empiric use of broad spectrum antimicrobials
Establish local antibiogram to guide initial empiric therapy
Limit antibiotic duration

* Used with patients with known or suspected MDRO infection or colonization.

PREVENTION OF INFECTION

Care at Point of Injury (Level I)

Initial care provided in the combat zone near or at the time of injury should emphasize safety of the patient and the personnel caring for the patient, controlling hemorrhage, and stabilization of breathing and airway per TCCC.[24] Wound care at this point consists of wound coverage and rapid evacuation. Casualty evaluation by a surgeon should occur within 6 hours of injury based on current doctrine (BII). If the intensity of battle and the environment allow, wounds should be covered with sterile bandages and the underlying bony structures stabilized to prevent further tissue injury (AII). If evacuation to surgical care is expected to be longer than 3 hours, antibiotics should be provided to the casualty as soon as possible (AII). The TCCC committee makes recommendations of which antibiotics to use in the combat environment in the setting of delayed evacuation.[26] The selection of these agents is based on spectrum, ease of administration, stability, and storage limitations. These antibiotic recommendations are not applicable to patients who can be rapidly removed from the battlefield or to those who have reached care at established medical facilities such as a battalion aid station (BAS). Based on mission, oral moxifloxacin has been placed into some personal medical kits (that also hold individual use items such as tourniquets, bandages, and pain medications) along with medic or corpsman medical kits. In the case of penetrating abdominal injury, shock, or when patients are unable to tolerate oral medication, the TCCC also has provided recommendations for intravenous or intramuscular agents to use in those wounded who cannot be evacuated immediately (Table 4).

Professional Medical Care Without Surgical Support (Levels I and IIa)

Care at a BAS (Level I) is typically provided by a physician assistant or a general medical officer (general medical officer (GMO)—physician with at least 1 year of postgraduate medical education, but typically a board-certified internist or internal medicine subspecialist, pediatrician or pediatric subspecialist, family physician, or emergency medicine physician). Level I facilities have no holding capability

Table 4 Antimicrobial Therapy for Prevention of Infection in Combat-Related Trauma During the Care of Casualties Under Tactical Situations When Evacuation is Expected to be Delayed (>3 h)

TCCC	Preferred Agent	Alternate Agent	Duration
Open extremity wounds	Moxifloxacin 400 mg PO	Levofloxacin 500 mg PO	1 dose
Penetrating abdominal injury, shock, or unable to tolerate oral medication	Ertapenem 1 g i.v./i.m.	Cefoxitin 2 g i.v./i.m.	1 dose

The three phases of tactical combat casualty care (TCCC). TCCC in which these antibiotic choices apply are "Care Under Fire", which is the care rendered by the medic or first responder at the scene while still under effective hostile fire, "Tactical Field Care", which is care rendered by the medic once no longer under effective hostile fire and medical equipment is still limited, and "Combat Casualty Evacuation Care", which is the care rendered once the casualty has been picked up by evacuation vehicles but has not reached a higher level of care including a battalion aid station (BAS) or forward surgical team (FST).

and are designed for routine sick call and trauma stabilization only. Typically, patients are evacuated from these facilities within 1 to 2 hours of injury in Iraq, with slightly longer delays in Afghanistan. Although enhanced casualty care can be provided, the primary goal for most injuries is stabilization and evacuation to a surgeon within 6 hours of injury (BII). Primary wound management consists of wound irrigation with removal of gross contamination (BIII). The type of fluid ideally used for irrigation is normal saline or sterile water, but potable water (AI) may be used in the event when these solutions are not available, with no change in outcome. Additives such as soap or antibiotics should not be included with irrigation fluids (DII). There is no "ideal" quantity of fluid, based upon size and location of injury, but 1 to 3 L is typically considered effective (BIII). The fluid should be delivered under low pressure (e.g. 1 L plastic bottles with several holes punched in the lid, applied by squeezing the bottle to propel fluid into the wound) (BII). High-pressure irrigation devices actually are associated with tissue damage. Wounds should be bandaged with a sterile dressing and underlying bony structures should be stabilized with available splinting materials to prevent further injury (AII). Eye injuries should be covered with hard protection (e.g. fox shield or similar improvised device). Pressure dressings over the eye should be avoided if a penetrating injury is suspected. Antibiotics, typically intravenous, should be given within 3 hours after injury (Table 5) (AII). The agent of choice should reflect the injury site requiring the broadest spectrum of bacterial activity (AI); excessively broad empiric antimicrobial therapy should be avoided (DIII). For example, if the casualty has a penetrating abdominal injury and an extremity injury, the antibiotic recommended for abdominal injury has activity in excess of those recommended for extremity injury and is adequate for both. If rapid evacuation of the casualty to surgical care is expected (less than 3 hours), provision of antibiotics can be deferred to the receiving facility, although many think antibiotics should be given as soon as possible. Tetanus immunoglobulin or toxoid should be given as indicated (see below) (AII). It is acceptable to leave small, retained metal fragments in soft tissues; these may not require evacuation or evaluation by a surgeon (BII).[27] However, roentgenogram evaluation is necessary to adequately determine location and extent of injury and this is not typically available at this level of care (see below).

Level IIa is typically a US Army medical company that has physician assistants and GMOs providing care with a holding capacity of up to 72 hours; no surgical care is available. Management strategies at Level I (BAS) apply here as well. Care should still emphasize wound management and evacuation to a surgeon within 6 hours of injury (BII). Limited roentgenogram capability is available (plain films only, no radiologist), so local management of retained metal fragments in soft tissue may be possible.

Care With Surgical Support (Levels IIb and III)

Surgical care provided in the combat zone is available at Level IIb facilities via forward surgical teams, which are designed for damage control surgery and short-term holding of patients. Level III facilities are tertiary care referral facilities in the combat zone that provide resuscitation, initial surgery, and postoperative care (intensive care unit, mechanical ventilation, and extended inpatient care) with enhanced diagnostic capabilities that include expanded laboratory support (including limited microbiology) and computed tomography scans. Although casualties should be evaluated by a surgeon within 6 hours of injury (BII), there is no requirement for surgery to occur within that time window (CIII).

At initial surgery there is no indication for pre- or postprocedure microbial cultures (EII). Unless there is gross evidence of infection at subsequent debridements, wound cultures do not adequately predict subsequent infections or infecting pathogens. Wound cultures may lead to unnecessary courses of broad-spectrum antibiotics and are thus highly discouraged.

Wounds should be aggressively debrided at the time of surgery (AII). Wound debridement should include removal of necrotic tissue, removal of readily retrieved foreign bodies, and careful evaluation of the remaining soft tissue. The goal of debridement is not to remove every small fragment (BII). For abdominal injuries, all nonviable solid and hollow viscera should be debrided and most solid organ (i.e. liver and pancreas) injuries drained. Small wounds to hollow viscus may be primarily repaired but caution should be applied for resection and re-anastomosis, especially in those with significant physiologic derangement. For colon wounds requiring resection, diversion is recommended in most cases. Skin should rarely be closed because of excessive infectious complications (BIII). Burns should be debrided early, typically at

Table 5 Selection and Duration of Antimicrobial Therapy for Prevention of Infection in Combat-Related Trauma

Injury	Preferred Agent(s)	Alternate Agent(s)	Duration
Skin, soft tissue, bone			
Skin, soft tissue, no open fractures	Cefazolin 1 g i.v. q8 h	Clindamycin 900 mg i.v. q8 h	72 h
Skin, soft tissue, with open fractures, exposed bone, or open joints	Cefazolin 1 g i.v. q8 h*	Clindamycin 900 mg i.v. q8 h*	72 h
Thoracic cavity			
Penetrating chest injury, with chest tube	Based on wound (see skin, soft tissue above)	Based on wound	NA
Abdomen			
Penetrating abdominal injury with suspected/known hollow viscus injury and soilage; may apply to rectal injuries as well	Antibiotics with broad-spectrum activity, including anaerobic activity. Options include cefoxitin 1–2 g i.v. q6–8 h, or piperacillin/tazobactam 4.5 g i.v. q6 h	Levofloxacin 750 mg i.v. once daily, or ciprofloxacin 400 mg i.v. q8–12 h and metronidazole 500 mg i.v. q6 h, or moxifloxacin 400 mg i.v. (monotherapy)	24 h after definitive cleaning
Maxillofacial			
Open maxillofacial fractures, or maxillofacial fractures with foreign body or fixation device	Cefazolin 2 g i.v. q8 h (higher dose recommended because of failures at 500 mg)	Clindamycin 900 mg i.v. q8 h	24 h
Central nervous system			
Penetrating brain injury	Cefazolin 1 g i.v. q8 h. Consider extending bacterial activity if gross contamination. Options included cefazolin and gentamicin and penicillin	Ceftriaxone 2 g i.v. q24 h. Consider extending bacterial activity if gross contamination. Options include cefazolin and gentamicin and penicillin. For penicillin allergic patient Vancomycin 1 g i.v. q12 h and ciprofloxacin 400 mg i.v. q8–12 h	5 d
Penetrating spinal cord injury	As above. Add anaerobic bacterial activity if abdominal cavity is involved. Options include metronidazole 500 mg i.v. q6–8 h	As above. Add anaerobic bacterial activity if abdominal cavity is involved. Options include metronidazole 500 mg i.v. q6–8 h	5 d
Eye			
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 fluoroescein staining)
Eye injury, penetrating	Prior to primary repair, no topical agents should be used unless directed by ophthalmology	Levofloxacin 750mg i.v./PO once daily	3–5 d
Burns			
Burns	Topical: large full thickness and contaminated burns should be treated with mafenide acetate once daily (mornings) and silver sulfadiazine once daily (afternoons) Systemic: no systemic treatment required	Either mafenide acetate or silver sulfadiazine to wounds twice daily. More limited (clean) full thickness burns may be treated with silver-impregnated dressings. Biobrane can be used in partial thickness burns	Until heated or grafted

* These guidelines do not advocate adding enhanced gram-negative bacterial activity in type III fractures (ciprofloxacin 400 mg i.v. q8 h or amikacin 15–20 mg/kg i.v. once daily).

the initial presentation to the surgeon or within the first 24 hours as the eschar serves as a major source of subsequent infections (AIII).

Certain injuries have a higher associated morbidity with immediate surgical intervention by an untrained subspecialist, which outweigh the infection preventing benefits of immediate debridement. Debridement of eye structures should wait until ophthalmologic surgical expertise is available. Not all foreign bodies introduced into the eye require urgent removal as infectious risks are small as long as removal of the foreign body occurs in a reasonable amount of time (BII). Foreign bodies can remain in the spine if there is no evidence of infection or neurologic decline (CIII). Not all foreign material introduced into the brain requires removal (BII). The destruction associated with attempts to completely debride the brain may have substantial negative functional impact.

Wounds should be adequately irrigated following debridement with copious fluid. For extremity injuries, 3 L of fluid are typically used for type I fractures, 6 L for type II fractures, and 9 L for type III fractures (Table 6) (BIII). For other wounds the recommendation is irrigation until the wounds are "clean". For abdominal injuries this is typically 6 L (BIII). The recommended irrigation fluids are normal saline or sterile water unless these are not available; then potable water is adequate (AI). There are no data supporting fluid additives and there is some data indicating they negatively impact wound healing (such as the toxic nature of betadine), and they can impair host defenses (DII). Fluid should be delivered under low pressure (typically less than 14 pounds per square inch) as high pressure has potential tissue and bone destructive properties (low-pressure irrigation (BIII); high-pressure irrigation [DII]).

Antibiotics should be given intravenously within 3 hours, and as soon as possible after injury (AII). The agent(s) used should cover the pathogens likely to be contaminating the wounds at the time of injury; these may include normal cutaneous and enteric flora such as *Staphylococcus*, *Escherichia coli*, and alimentary tract anaerobes (AI). Initial antibacterial activity should not be directed at multidrug-resistant pathogens such as *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, or *Klebsiella pneumoniae* (DII). Given the low number of methicillin-resistant *Staphylococcus aureus* (MRSA) infections and clinical data indicating that drainage and not antibiotics is the primary therapy of abscesses (even those secondary to community-acquired MRSA), empiric MRSA therapy with vancomycin does not appear necessary (DII). Agents should again reflect overlapping activity focused on the injury that requires the broadest spectrum of bacterial activity. Burn patients do not require systemic antibiotics unless there is evidence of infection or if antibiotics are indicated for treatment of other injuries (DI). There are data that suggest the use of broad-spectrum antibiotics often leads to the development of subsequent infection with resistant pathogens. The duration of antibiotic therapy should be minimized as indicated in the Table 5 (BII). Prolonged therapy has been shown to worsen outcomes. Antibiotics should not be used just because the wound is "open" or because a drain remains in place (BIII). The presence of a chest tube alone does not require ongoing antimicrobial therapy. The role of topical antimicrobial therapy is clear for burn patients (AII). For full-thickness burn wounds, mafenide acetate every morning and silver sulfadiazine every evening is recommended. Silver sulfadiazine once daily is acceptable for partial thickness burns or for burns of limited extent. When twice-daily dressing changes are impossible, once per day changes will still provide significant benefit. It is essential to thoroughly debride and cleanse the wound at each dressing change using chlorhexidine gluconate (4%). For partial-thickness burns, biobrane is adequate for simple coverage of clean wounds. For burns of limited extent (e.g. $<$30% total body surface area), silver impregnated dressings are adequate. Antibiotic impregnated beads for open fractures may be an appropriate therapy for personnel not being evacuated out of the combat zone who will also have an appropriate follow-up (BII); their use is not supported for US personnel being evacuated 1 to 3 days after injury (DIII). Tetanus immunotherapy should be implemented as described in a subsequent section (AII).

Combat wound management includes delayed primary closure (not in theater) for extremity wounds; however, injuries to the face and brain require early closure of the mucosal lining or dura to decrease infections (which are significantly higher in the CNS without early closure) and cosmetic complications (BII). Early primary repair of complex or destructive colonic injuries is not recommended (BII), especially if associated with massive blood transfusion, ongoing hypotension, hypoxia, reperfusion injury, multiple other injuries, high-velocity injury, or extensive local tissue damage. However, simple, isolated colon injuries may be repaired primarily (AI). Skin should not be closed if there is a colon injury

Table 6 **Grading of Extremity Injuries With Fracture and Their Infection Risk**

Type of Open Fracture	Description	Infection Risk* (%)
Type I	Puncture wound ≤1 cm	0–2
Type II	Laceration wound ≥1 cm Moderate soft-tissue damage and crushing Bone coverage adequate and comminution is minimal	2–10
Type III		10–50
A	Extensive soft-tissue damage, severe crushing, adequate bone coverage	
B	Periosteal damage and bone exposure with severe contamination and bone comminution, flap needed	
C	Arterial injury requiring repair	

* Based on data from civilian trauma. Tibial fractures have up to 2 times higher risk of infection than other injury sites with similar types of open fracture.

or extensive devitalized tissue because of excessive infectious complications (BIII). Vacuum-assisted closure (VAC) has been shown to be effective for personnel not being evacuated out of the combat zone when used in extremity and abdominal injuries (BII). The role of VAC in personnel being evacuated is currently being evaluated and initial results are encouraging. At this time, wound VAC should be cautiously used during air evacuation until further data are available (CIII). It is currently postulated that limitations of VAC usage in this setting are largely secondary to a need for proper training in their use during flight. In the past cranial bone has been retained in the abdominal wall, but given high infection rates and successful use of cranial prosthetics, this procedure has been discontinued (EIII).

Underlying bony structures should be stabilized to prevent subsequent infections. External fixation is currently recommended at Level III care for extremity wounds (AII); however, there are data reporting infectious complications with transcutaneously placed pins, so close clinical monitoring is necessary.

To prevent long-term infectious complications associated with trauma, patients requiring splenectomy should receive immunization against encapsulated organisms (e.g. *Haemophilus influenzae*, pneumococcal, and meningococcal vaccines), ideally at 14 days of injury as this provides optimal immune reconstitution (CIII).

Care of Personnel not Evacuated Rapidly out of the Combat Zone

In the current combat zones, there is a large non-US patient population that is receiving damage control surgery and definitive therapy without evacuation to higher levels of care. This population frequently represents 60% to 80% of all injured casualties admitted to the Level III facilities. These patients should be managed according to the guidelines for Levels IV and V in the adjoining articles, applying criteria for therapy based upon nosocomial, not community-acquired infections after admissions of greater then 72 hours. These patients may be at significant risk for multidrug-resistant colonization and infection as they often remain in facilities for long periods and have higher risks of developing MDRO infection, especially if aggressive infection control procedures are not followed. As such, they should be carefully managed to prevent nosocomial transmission within the facility, and indirectly, throughout the evacuation chain. In the combat zone, these patients should be evaluated for signs and symptoms of infection, and aggressive management strategies for the prevention of nosocomial infections should be implemented. This should include infection control procedures outlined above and aggressive antibiotic control programs.

Other Issues

Tetanus Immunotherapy

Therapy for tetanus is well founded and should be standard of care. Immunized individuals should receive a booster dose of tetanus toxoid based on standard guidelines. Those subjects who have not been immunized should receive antitetanus human immunoglobulin in most cases, unless wounds are clean and care not delayed. In addition, these casualties should receive tetanus toxoid at the time of injury and again at 4 weeks and 6 months later.

Small Retained Fragments

The weaponry commonly used in ground combat operations can result in numerous small fragments lodged into the soft tissue of the body. Often, the sheer numbers of fragments make them difficult or impossible to remove. Nonoperative management is recommended in these patients if they have soft tissue injuries only (no fractures, no joint involvement, no major vascular involvement, and no break of pleura or peritoneum), wound entry/exit lesions less than 2 cm in maximum dimension, and do not show evidence of frank infection (BII). Management should include wound irrigation if possible, cleaning and dressing the wound, and administration of antitetanus immunoglobulin and toxoid as necessary. A single dose of antibiotics may be employed for management of these wounds as described in the Table 5 for extremity injury. Some suggest a 5-day course of antimicrobial therapy, but this is not likely needed. Removal of intraocular fragments may be delayed in the absence of infection (endophthalmitis); but consultation with an ophthalmologist as soon as possible is required.

AREAS FOR FUTURE RESEARCH

At this time, there are countless areas needing further randomized, controlled studies to determine the best treatment strategies for prevention of combat-related injury infections. The best infection control measures to prevent subsequent nosocomial infections are also needed. Priorities should include focus on evaluation of ideal antimicrobial regimens for use at the time of injury and the ideal duration of antibiotic therapy. Further assessment of the role of wound VAC and use of earlier closure of some lower risk injuries is also needed. There needs to be a method to provide physicians the ability to rapidly detect pathogens that are associated with infection to not only initiate therapy as early as possible but also to limit the exposure of patients to prolonged overly broad-spectrum antibiotics, especially in an environment associated with rapid evacuation.

CLINICAL PRACTICE GUIDELINE FOR THE PREVENTION OF INFECTION AFTER COMBAT-RELATED INJURIES

I. Care at point of injury (Level I)
   A. Evacuate to surgical care within 6 hours (BII)
   B. Bandage wound with sterile dressing; stabilize fractures for evacuation to Level IIb/III (AII)
   C. Single dose of oral or intravenous (i.v.) or intramuscularly (i.m.) antibiotics (within 3 hours of injury) (Table 4) should only be given if evacuation is delayed (AII)

II. Patient care without surgical support (Levels I and IIa)
   A. Level I (BAS)
      1. Evacuate to surgical evaluation within 6 hours (BII)
      2. Primary wound management consists of irrigation to remove gross contamination (BIII); use normal saline, sterile or potable water (AI); under low pressure (BII) with no additives (DII)
      3. Bandage wound with sterile dressing (avoid pressure dressings over eyes) (AII)
      4. Intravenous antibiotics within 3 hours of injury (AII); i.v. infusion of antibiotics is preferred over i.m. in hemodynamically compromised patients
      5. Antibiotic choice per Table 5 (AI) without enhanced gram-negative activity (DIII)
      6. Tetanus immunoglobulin and toxoid as appropriate (AII)
   B. Level IIa (medical company)
      1. Same as Level I (BAS)
      2. Consider treating at the local facility with a single dose of antibiotics, without surgical evaluation for small retained fragments that only involve soft tissue injury (roentgenogram confirmation of no bone involvement, no joint or vascular involvement, and no break of pleura or peritoneum), wound entry/exit lesions less than 2 cm in maximal dimension, wound not frankly infected (BII)

III. Care with surgical support (Levels IIb and III)
   A. Casualties should undergo surgical evaluation within 6 hours of injury (BII); surgical intervention can be delayed past 6 hours based on tactical reasons (CIII)
   B. Do not obtain routine pre- or post-procedure microbial cultures (EII); cultures should only be obtained when there is clinical evidence of infection
   C. Wounds should be aggressively debrided with removal of all necrotic tissue and foreign bodies that can be easily reached (AII); eye (BII) and spine injuries without neurologic compromise (CIII) can await surgical debridement until surgical expertise is available; cerebral foreign bodies may remain if removal would cause excess damage (BII)
   D. Wounds should be irrigated until clean; extremity injuries should be irrigated based upon type of fracture (type I [3 L], type II [6 L], and type III [9 L]) (BIII); abdominal trauma typically requires 6 L of fluid (BIII). Irrigation fluids can include normal saline or sterile water; potable water may be used in the event when these solutions are not available (AI). Fluid additives are not recommended (DII); no high-pressure irrigation should be performed (BIII low pressure (less than 14 PSI), DII high pressure)
   E. Antibiotics should be infused within 3 hours of injury (AII); avoid overly broad-spectrum antibiotics and minimize duration (Table 5) (for extremity injuries with fracture: first-generation cephalosporin [AI]; enhanced gram-negative activity agent is not recommended [DIII]); antibiotics activity should best reflect the most contaminated site (abdominal $>$ face $>$ CNS/eye/extremity); duration should be short (Table 5) (BII) and not extended for open wounds, drains, or external fixation devices (BIII); antibiotic cement can be used for extremity injuries in patients not evacuated (BII), but should not be used for patients expected to be evacuated or transferred in 1 to 3 days (DIII); topical wound therapy is recommended for burn patients (AII), but not for other injuries; retained foreign body in the eye, spine, or brain should receive antibiotics as indicated in the table
   F. Adjunct therapy includes tetanus immunoglobulin and toxoid as necessary (AII); immunization against encapsulated organisms at 14 days after trauma for patients who have their spleen removed (CIII)
   G. Extremity wounds should be left open in theater (EII, immediate primary closure); skin should not be closed if there is a colon injury or extensive devitalized tissue because of excessive infectious complications (BIII); early primary repair of complex or destructive colonic injuries is not recommended (BII), especially if associated with massive blood transfusion, ongoing hypotension, hypoxia, reperfusion injury, multiple other injuries, high-velocity injury, or extensive local tissue damage; simple, isolated colon injuries may be repaired primarily (AI).VAC appears effective in the combat zone (BII) but its role during air evacuation is unclear at this time (CIII); if no evacuation at 3 to 5 days consider closing wounds if no evidence of infection (BII); injuries to the face (BII) and brain (BIII) require early closure of the mucosal lining and dura or skin covering the brain
   H. Extremities should be stabilized by external fixation if required but close clinical monitoring for infection is recommended (AII)

IV. Care associated with personnel not evacuated rapidly out of the combat zone
   A. Should reflect Levels IV and V care outlined in the accompanying reviews; facility-specific antibiograms should be developed (AII); infection control procedures should be implemented (AII); management strategies after 72 hours of admission should emphasize nosocomial infections

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