

## Chapter 10

# Infections

### Introduction

**All wounds incurred on the battlefield are grossly contaminated with bacteria. Most will become infected unless appropriate treatment is initiated quickly.**

The battlefield environment is conducive to wound infection due to the:

- Absence of “sterile” wounding agents on the battlefield. All foreign bodies (wounding projectile fragments, clothing, dirt) are contaminated with bacteria.
- High-energy projectile wounding, which causes:
  - devitalized tissue,
  - hematoma, and
  - tissue ischemia.
- Delay in casualty evacuation.

### Diagnosis of a Wound Infection

- The four “-or’s”: dolor, rubor, calor, and tumor—**pain and tenderness, redness, warmth, and swelling.**
- Drainage or discharge, ranging from frank pus to the foul “dishwater” discharge of clostridial infection.
- Crepitus, radiographic evidence of soft-tissue gas, epidermal blistering, and/or epidermal necrosis are the hallmarks of necrotizing soft-tissue infection (eg, clostridial gas gangrene or necrotizing fasciitis).
- Systemic effects: fever, leukocytosis, unexplained tachycardia, or hypotension.
- Confirm diagnosis by Gram stain and culture, if available, and/or tissue biopsy.

## Common Microorganisms Causing Battlefield Infections

- Gram-positive cocci:
  - staphylococci,
  - streptococci, and
  - enterococci.
- Gram-negative rods:
  - *Escherichia coli*, *Proteus*, and *Klebsiella*.
  - *Pseudomonas*, *Enterobacter*, *Acinetobacter*, and *Serratia* are common nosocomial pathogens usually expected among casualties who have been hospitalized for an extended period, not those fresh off the battlefield.
- *Salmonella*, *Shigella*, and *Vibrio* should be suspected in cases of bacterial dysentery.
- Anaerobic gram-positive and gram-negative rods:
  - *Clostridia*,
  - *Bacteroides*, and
  - *Prevotella* species.
- Fungal species: *Candida* species should be suspected in casualties hospitalized for prolonged periods, those malnourished or immunosuppressed, or those who have received broad-spectrum antibiotics, adrenocortical steroids, or parenteral nutrition. Empiric therapy should be considered in appropriate patients with presumptive evidence of fungal infection.

## Common Patterns of Infection

- **Skin, soft tissue, muscle, and bone:** Primarily due to staphylococcal, streptococcal, and clostridial species. These infections include:
  - wound abscess,
  - cellulitis,
  - septic arthritis,
  - osteomyelitis,
  - necrotizing fasciitis, and
  - gas gangrene.
- **Intracranial:** Meningitis, encephalitis, and abscess—commonly from staphylococci and gram-negative rods—are difficult to treat due to the impervious nature of the meninges to common antibiotics.

- **Orofacial and neck:** Gram-positive cocci and mouth anaerobes are generally responsive to surgery and clindamycin.
- **Thoracic cavity:** Empyema (usually staphylococcal) and pneumonia (*Staphylococcus*, *Streptococcus*, and *Pseudomonas*), especially among those on prolonged mechanical ventilation or those casualties prone to aspiration (polymicrobial).
- **Intraabdominal:** Include posttraumatic or postoperative abscess and peritonitis due to *Enterococcus*, gram-negative rods, and anaerobic bacilli. *Clostridium difficile* is often responsible for a potentially severe diarrheal colitis that occurs following the administration of even one dose of antibiotic.
- **Systemic sepsis:** A syndrome caused by a bloodborne or severe regional infection resulting in a global inflammatory response (fever, leukocytosis, tachycardia, tachypnea, and possibly hypotension).
  - A similar inflammatory response without infection can be caused by a focus of retained necrotic tissue or the mere act of sustaining severe trauma.
  - Culprit microorganisms will not be recovered in all cases of sepsis syndrome.
  - Although typically associated with gram-negative organisms, any bacterial or fungal agent can cause sepsis.

**Prompt surgical source control consisting of copious irrigation and thorough debridement are the cornerstones of prevention and treatment of all war wound infections.**

## Treatment

### General Principles

- Antibiotic treatment should begin as early as possible, ideally within an hour after injury, and be repeated in the prophylaxis of war wound infection.
- Optimally, surgical debridement should be achieved within 6 hours of injury.
- Following initial exploration and debridement, the wound should be sufficiently irrigated to ensure that all dead material, bacterial contamination, and foreign material have been washed from the wound.

- To minimize gross contamination, wounds should be irrigated with saline or sterile water by bulb syringe or gravity flow from irrigant bag.
- The skin is left open, and a lightly moistened sterile gauze dressing is applied.
- For larger wounds, placement of a vacuum-assisted closure device may be indicated.
- Ballistic wounds should NEVER be closed in theater. Multiple irrigations and debridements are required to remove all ischemic and contaminated tissue.
- Antibiotics should be started as soon as possible after wounding, then continued for 24 hours, depending on the size, extent of destruction, and degree of contamination of the wound.
  - If time from wounding to initiation of antibiotics is >6 hours, or time from wounding to surgery is >12 hours, begin an antibiotics regimen for established infection.
- The choice of empiric antibiotic is dependent on the part of the body injured (Tables 10-1 and 10-2).
- Once a battlefield wound has become infected, treatment is two-fold: surgical and medical.
  - Surgical strategy remains the same: Open the wound, remove infected and necrotic tissue, and inspect for foreign material.
  - Drainage is generally used in abscess cavities to prevent premature closure and reformation.
  - Empiric broad-spectrum antibiotic therapy is initiated against likely pathogens per current CPG guidelines.
  - Ideally, obtain cultures and tailor therapy to cover the actual pathogens recovered on Gram stain and culture. However, routine bacteriology is often not available in forward medical facilities.
  - The patient is returned to the operating room every 1–2 days for serial irrigation and debridement.

### Specific Infections

- Tetanus.
  - Battlefield wounds are “tetanus-prone” due to high levels of contamination with *Clostridium tetani*.

**Table 10-1. Recommendations to Prevent Infections Associated With Combat-Related Injuries Based on Level of Care**

Level of Care	Care Category	Recommendations
<b>Role 1 (Prehospital)</b>	Initial care in the field	<ul style="list-style-type: none"> <li>● Bandage wounds with sterile dressings (avoid pressure over eye wounds)</li> <li>● Stabilize fractures</li> <li>● Transfer to surgical support as soon as feasible</li> </ul>
	Post-injury antimicrobials	<ul style="list-style-type: none"> <li>● Provide single dose point of injury antimicrobials (Appendix B) if evacuation is delayed or expected to be delayed</li> </ul>
<b>Role 1 and Role 2 without surgical support (IIa)</b>	Post-injury antimicrobials	<ul style="list-style-type: none"> <li>● Provide IV antimicrobials for open wounds (Appendix B) as soon as possible (within 3 h)</li> <li>● Provide tetanus toxoid and immune globulin as appropriate</li> <li>● Gram-negative coverage with aminoglycoside or fluoroquinolone not recommended</li> <li>● Addition of penicillin to prevent clostridial gangrene or streptococcal infection not recommended</li> <li>● Redose antimicrobials if large volume blood product resuscitation</li> <li>● Use only topical antimicrobials for burns</li> </ul>
	Debridement and irrigation	<ul style="list-style-type: none"> <li>● Irrigate wounds to remove gross contamination with normal saline, sterile, or potable water; add middle point without additives</li> <li>● Do not attempt to remove retained deep soft-tissue fragments if criteria met;<sup>†</sup> provide Cefazolin 2 g IV × 1 dose</li> </ul>
<b>Role 2 with surgical support and Role 3</b>	Post-injury antimicrobials	<ul style="list-style-type: none"> <li>● Provide intravenous antimicrobials (Appendix B) as soon as possible (within 3 hours).</li> <li>● Provide tetanus toxoid and immune globulin as appropriate.</li> <li>● Gram-negative coverage with aminoglycoside or Fluroquinolone not recommended.</li> </ul>

(Table 10-1 continues)

Table 10-1 *continued*

Level of Care	Care Category	Recommendations
		<ul style="list-style-type: none"><li>● Addition of penicillin to prevent clostridia gangrene or streptococcal infection is not recommended.</li><li>● Redose antimicrobials if large volume blood product resuscitation.</li><li>● Use only topical antimicrobials for burns</li><li>● Antimicrobial beads or pouches may be used.</li><li>● Provide post splenectomy immunizations if indicated.</li></ul>
	Debridement and irrigation	<ul style="list-style-type: none"><li>● Irrigate wounds to remove contamination with normal saline or sterile water using bulb irrigation, gravity irrigation, or pulse lavage without additives. For open fractures, use 3 L for each type I, 6 L for each type II, and 9 L for each type III extremity fractures.</li><li>● Repeat debridement and irrigation every 24-48 hours until wound is clean and all devitalized tissue is removed.</li><li>● Do not attempt to remove retained deep soft tissue fragments if criteria met. Provide Cefazolin 2 gm IV x 1 dose.</li><li>● Do not obtain cultures unless infection is suspected.</li></ul>
	Other surgical management	<ul style="list-style-type: none"><li>● Surgical evaluation as soon as possible.</li><li>● Only dural and facial wounds should undergo primary closure.</li><li>● Negative pressure wound therapy (NPWT) can be used.</li><li>● External fixation (temporary spanning) of femur/tibia fractures.</li><li>● External fixation (temporary spanning) OR splint immobilization of open humerus/forearm fractures.</li></ul>
Role 4	Post-injury antimicrobials	<ul style="list-style-type: none"><li>● Complete course of post-injury antimicrobials (Appendix B)</li><li>● Antimicrobial beads or pouches may be used</li><li>● Provide post splenectomy immunizations if indicated</li></ul>

(Table 10-1 *continues*)

Table 10-1 *continued*

Level of Care	Care Category	Recommendations
	Debridement and irrigation	<ul style="list-style-type: none"> <li>● Irrigate wounds to remove contamination with normal saline or sterile water using bulb</li> <li>● Irrigation, gravity irrigation, or pulse lavage without additives. For open fractures, use 3 L for each type I, 6 L for each type II, and 9 L for each type III extremity fractures.</li> <li>● Repeat debridement and irrigation every 24-48 hours until wound is clean and all devitalized tissue is removed.</li> <li>● Do not attempt to remove retained deep soft tissue fragments if criteria met.<sup>†</sup> Provide Cefazolin 2 gm IV x 1 dose</li> <li>● Do not obtain cultures unless infection is suspected</li> </ul>
	Other surgical management	<ul style="list-style-type: none"> <li>● Wounds should not be closed until 3-5 d post-injury when wound is clean and all devitalized tissue is removed.</li> <li>● Only dural and facial wounds should undergo primary closure.</li> <li>● Negative pressure wound therapy (NPWT) can be used.</li> <li>● External fixation (temporary spanning) of femur/tibia fractures.</li> <li>● External fixation (temporary spanning) OR splint immobilization of open humerus/forearm fractures.</li> </ul>

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

Reproduced from: Joint Trauma System Clinical Practice Guideline: Infections Prevention in Combat-Related Injuries. August 8, 2016. CPG ID: 24. Appendix A.

**Table 10-2. Postinjury Antimicrobial Agent Selection and Duration Based Upon Injury Pattern\***

<b>Injury</b>	<b>Preferred Agent(s)</b>	<b>Alternate Agent(s)</b>	<b>Duration</b>
<b>Extremity wounds (include skin, soft tissue, and bone)</b>			
Skin, soft tissue, no open fractures	Cefazolin 2 gm IV q6–8h <sup>†,‡</sup>	Clindamycin (300–450 mg PO TID or 600 mg IV q8h)	1–3 days
Skin, soft tissue, with open fractures, exposed bone, or open joints	Cefazolin 2 gm IV q6–8h <sup>†,‡,§</sup>	Clindamycin 600 mg IV q8h	1–3 days
<b>Thoracic wounds</b>			
Penetrating chest injury without esophageal disruption	Cefazolin 2 gm IV q6–8h <sup>†,‡</sup>	Clindamycin (300–450 mg PO TID or 600 mg IV q8h)	1 day
Penetrating chest injury with esophageal disruption	Cefazolin 2 gm IV q6–8h <sup>†,‡</sup> PLUS metronidazole 500 mg IV q8–12h	Ertapenem 1 g IV × 1 dose OR moxifloxacin 400 mg IV × 1 dose	1 day after definitive washout
<b>Abdominal wounds</b>			
Penetrating abdominal injury with suspected/known hollow viscus injury and soilage; may apply to rectal/perineal injuries as well	Cefazolin 2 gm IV q6–8h <sup>†,‡</sup> PLUS metronidazole 500 mg IV q8–12h	Ertapenem 1 gm IV × 1 dose or moxifloxacin 400 mg IV × 1 dose	1 day after definitive washout
<b>Maxillofacial and Neck Wounds</b>			
Open maxillofacial fractures, or maxillofacial fractures with foreign body or fixation device	Cefazolin 2 gm IV q6–8h <sup>††</sup>	Clindamycin 600 mg IV q8h	1 day

(Table 10-2 continues)



Table 10-2 *continued*

Injury	Preferred Agent(s)	Alternate Agent(s)	Duration
<b>Central nervous system wounds</b>			
Penetrating brain injury	Cefazolin 2 gm IV q6–8h. <sup>†‡</sup> Consider adding metronidazole 500 mg IV q8–12h if gross contamination with organic debris	Ceftriaxone 2 gm IV q24h if gross contamination with organic debris. For penicillin allergic patients, Vancomycin 1 gm IV q12h PLUS ciprofloxacin 400 mg IV q8–12h	5 days or until CSF leak is closed, whichever is longer
Penetrating spinal cord injury	Cefazolin 2 gm IV q6–8h. <sup>†‡</sup> ; ADD metronidazole 500 mg IV q8–12h if abdominal cavity is involved	As above. ADD metronidazole 500 mg IV q8–12h if abdominal cavity is involved	5 days or until CSF leak is closed, whichever is longer
<b>Eye wounds</b>			
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. Prior to primary repair, no topical agents should be used unless directed by ophthalmology		7 days or until evaluated by an ophthalmologist

(Table 10-2 continues)

Table 10-2 *continued*

Injury	Preferred Agent(s)	Alternate Agent(s)	Duration
<b>Burns</b>			
Superficial burns	Topical antimicrobials with twice daily dressing changes (include mafenide acetate** or silver sulfadiazine; may alternate between the two), OR silver-impregnated dressing changed q3–5d, 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
<b>Point-of-injury/delayed evacuation<sup>††</sup></b>			
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 q12h if penetrating abdominal injury, shock, or unable to tolerate PO medications	Single dose therapy

(Table 10-2 *continues*)

Table 10-2 *continued*

\*Post-injury antimicrobial agents are recommended to prevent early post-traumatic infectious complications, including sepsis, secondary to common bacterial flora. Selection is based on narrowest spectrum and duration required to prevent early infections prior to 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 (MDR) or other nosocomial pathogens may be causing infection.

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

<sup>‡</sup>Pediatric dosing: cefazolin, 20-30 mg/kg IV q6-8h (maximum, 100 mg/kg/day); metronidazole, 7.5 mg/kg IV q6h; clindamycin 25-40mg/kg/day IV divided q6-8h; ertapenem, 15 mg/kg IV or IM q12 (children up to 12 years) or 20 mg/kg IV or IM once daily (children over 12 years; maximum, 1 gm/day); ceftriaxone, 100 mg/kg/day IV divided q12-24h (dosing for CNS injury); levofloxacin, 8 mg/kg IV or PO q12h (levofloxacin is only FDA-approved in children for prophylaxis of inhalational anthrax in children > 6 months of age, but this dose is commonly used for other indications); vancomycin 60 mg/kg/day IV divided q6h (dosing for CNS injury); ciprofloxacin, 10mg/kg IV (or 10-20mg/kg PO) q12h.

<sup>§</sup>These guidelines do not advocate adding enhanced Gram-negative bacteria coverage (i.e., addition of fluoroquinolone or aminoglycoside antimicrobials) in type III fractures.

<sup>\*\*</sup>Mafenide acetate is contraindicated in infants less than 2 months of age.

<sup>††</sup>Post-injury antimicrobial therapy as suggested by the Committee on Tactical Combat Casualty Care (CoTCCC).

Reproduced from: Joint Trauma System Clinical Practice Guideline: Infections Prevention in Combat-Related Injuries. August 8, 2016. CPG ID: 24. Appendix B.

- Bacteria grow anaerobically and release a central nervous system (CNS) toxin that results in muscle spasm, trismus, neck rigidity, and back arching.
- **In addition to surgical debridement of war wounds, additional prophylactic measures for tetanus-prone wounds include:**
  - ◆ Administration of 0.5 mL intramuscular (IM) of **tetanus toxoid** if prior tetanus immunization is uncertain, if the patient received less than three doses of tetanus vaccine or it has been >5 years since the last dose.
  - ◆ Administration of 250–500 U IM of **tetanus immune globulin** in a separate syringe and at a separate site from the toxoid if prior tetanus immunization is uncertain or less than three doses.

- Treatment for established tetanus includes:
  - ◆ IV antibiotics (penicillin G, 24 million U/d; or doxycycline, 100 mg bid; or metronidazole, 500 mg q6h for 7 days).
  - ◆ Tetanus immune globulin.
  - ◆ Wound debridement as needed.
  - ◆ IV diazepam to ameliorate the muscle spasm.
  - ◆ Place patient in a dark, quiet room free of extraneous stimulation.
  - ◆ May warrant endotracheal intubation, mechanical ventilation, and neuromuscular blockade.
- **Soft-tissue infections.**
  - **Cellulitis** is manifested by localized skin erythema, heat, tenderness, and swelling or induration.
    - ◆ Treatment: IV antibiotics against streptococcal and staphylococcal species (IV nafcillin, Cefazolin, or, in the penicillin-allergic patient, clindamycin or vancomycin).
  - **Postoperative wound infections** become evident by wound pain, redness, swelling, warmth, and/or foul or purulent discharge, with fever and/or leukocytosis.
    - ◆ Treatment: **Open the wound**, drain the infected fluid, and debride any necrotic tissue present.
    - ◆ The wound is left open and allowed to close via secondary intention.
  - **Necrotizing soft-tissue infections** are the most dreaded infections resulting from battlefield wounding. These include **clostridial myonecrosis (gas gangrene)** and **polymicrobial infections** caused by *Streptococcus*, *Staphylococcus*, *Enterococcus*, *Enterobacteriaceae*, *Bacteroides*, and *Clostridia*.
    - ◆ The organisms create a rapidly advancing infection within the **subcutaneous tissues** and/or **muscle** by producing exotoxins that lead to bacteremia, toxemia, and septic shock.
    - ◆ **All layers of soft tissue can be involved**, including skin (blistering and necrosis), subcutaneous tissue (panniculitis), fascia (fasciitis), and muscle.
    - ◆ Clinical manifestations begin locally with severe pain, crepitus, and with *Clostridia*, a thin, brown, foul-smelling discharge.

- ◆ The skin may be tense and shiny, showing pallor or a bronze color.
- ◆ Systemic signs include fever, leukocytosis, mental obtundation, hemolytic anemia, and hypotension, progressing rapidly to multiple organ failure and death in untreated or undertreated cases.
- ◆ The diagnosis is made by a history that seems out of proportion to the extent of injury combined with palpable or radiographic soft-tissue gas (air in subcutaneous tissue and/or muscle).
- ◆ Absence of soft-tissue gas does not exclude diagnosis of necrotizing infection.
- ◆ **Treatment is surgical**, including early, comprehensive, and repeated (every 12–24 hours) debridement of all dead and infected tissue, combined with broad-spectrum **antibiotics**.
- ◆ **Excision** of affected tissue must be as radical as necessary (including amputation or disarticulation) to remove all non-viable tissue (discolored, noncontractile, or nonbleeding). **Clinical judgment is paramount**.
- ◆ Identification of causative organisms is often problematic; treatment must be aimed at all possible organisms.
- ◆ **IV antibiotic therapy**.
  - ◇ **Clindamycin**, 900 mg q8h; **plus penicillin G**, 4 million U q4h; **plus gentamicin**, 5–7 mg/kg qd.
  - ◇ As a **substitute for clindamycin**: Metronidazole, 500 mg q6h.
  - ◇ As a **substitute for penicillin**: Ceftriaxone, 2.0 g q12h, or erythromycin, 1.0 g q6h.
  - ◇ As a **substitute for gentamicin**: Ciprofloxacin, 400 mg q12h.
- ◆ Alternative regimen: Imipenem, 1 g IV q6h.
- **Intraabdominal infections**.
  - Regimens (start as soon as possible and continue for **24 hours** post-op):
    - ◆ **Single agent**: cefotetan, 1.0 g q12h; or ampicillin/sulbactam, 3 g q6h; or cefoxitin, 1.0 g q8h.
    - ◆ **Triple agent**: ampicillin, 2 g q6h; **plus** anaerobic coverage (metronidazole, 500 mg q6h; or clindamycin, 900 mg every 8 hours); **plus** gentamicin, 5–7 mg/kg/day.

- **Established** intraabdominal infection (peritonitis or abscess).
  - ◆ Same regimen as above, except continue for 7–10 days.
  - ◆ Drain all abscesses.
- **Pulmonary infections.**
  - **Empyema** (generally streptococcal) following penetrating thoracic trauma is typically due to contamination from the projectile, chest tubes, or thoracotomy.
  - Diagnosis: loculations, air/fluid levels on radiograph, pleural aspirate.
  - Treatment.
    - ◆ Initial treatment is prevention during all interventions. Once confirmed, a video-assisted thoracostomy (VATS) or formal thoracotomy is indicated. **Chest tubes are not adequate treatment.**
    - ◆ Cefotaxime, or ceftriaxone, or cefoxitin, or imipenem.
  - **Pneumonia** is most frequently due to prolonged mechanical ventilation or aspiration in patients with severe traumatic brain injury (TBI).
  - The diagnosis is clinical and supported through radiographical findings of a new pulmonary infiltrate combined with:
    - ◆ Fever or leukocytosis.
    - ◆ Thick secretions
    - ◆ Sputum analysis showing copious bacteria and leukocytes.
  - Empiric therapy is directed toward likely pathogens.
    - ◆ **Aspiration:** Streptococcal pneumonia, coliforms, and oral anaerobes are likely. IV antibiotics—such as ampicillin/sulbactam, clindamycin, or cefoxitin—have been proven effective.
    - ◆ **Ventilator-associated pneumonia:** *Staphylococcus*, *Pseudomonas*, and other nosocomial *Enterobacteriaceae*. Broad coverage is best with such agents as imipenem, ceftazidime, or piperacillin/tazobactam plus vancomycin for methicillin-resistant *Staphylococcus aureus*. Ciprofloxacin can be considered for double-coverage against *Pseudomonas* if sufficient concern exists.

## Systemic Sepsis

Sepsis can be defined as infection combined with a prolonged systemic inflammatory response that includes two or more of the following conditions:

- Tachycardia.
- Fever or hypothermia.
- Tachypnea or hyperventilation.
- Leukocytosis or acute leukopenia.

Progression to septic shock is manifested by systemic hypoperfusion: profound hypotension, mental obtundation, or lactic acidosis.

It is often difficult to identify the source of sepsis, but it is **an important factor** in determining the outcome. Potential sources of occult infection include:

- An undrained collection of pus, such as a wound infection, intraabdominal abscess, sinusitis, or perianal abscess.
- Ventilator-associated pneumonia.
- Urinary tract infection.
- Disseminated fungal infection.
- Central intravenous catheter infection.
- Acalculous cholecystitis.

The newly revised Surviving Sepsis Campaign (2016) recommends:

- Empiric broad-spectrum therapy with one or more antimicrobials to cover all likely pathogens. IV administration should be initiated within one hour of presentation.
- Treatment of sepsis-induced shock with at least 30 mL/kg of IV crystalloid fluid within the first 3 hours.
- Fluid resuscitation should be guided by frequent reassessment of hemodynamics.
- If goal mean arterial pressure (MAP) >65 is not attained with fluid resuscitation, the initiation of vasopressors is indicated.
  - First line agent: norepinephrine.
  - Second line agents: Addition of vasopressin (.03 U/min) or epinephrine.

**Table 10-3. Spectrum and Dosage of Selected Antibiotic Agents**

Agent	Antibacterial Spectrum	Dosage
Penicillin G	<i>Streptococcus pyogenes</i> , penicillin-sensitive <i>Streptococcus pneumoniae</i> , clostridial spp.	4 mU IV q4h
Ampicillin	Enterococcal spp., streptococcal spp., <i>Proteus</i> , some <i>Escherichia coli</i> , <i>Klebsiella</i>	1–2 g IV q6h
Ampicillin/sulbactam	Enterococcal spp., streptococcal spp., <i>Staphylococcus</i> ,* <i>E coli</i> , <i>Proteus</i> , <i>Klebsiella</i> , clostridial spp., <i>Bacteroides/Prevotella</i> spp.	3 g IV q6h
Nafcillin	Staphylococcal spp.,* streptococcal spp.	1 g IV q4h
Piperacillin/clavulanate	Enterococcal spp., streptococcal spp., <i>Staphylococcus</i> ,* <i>E coli</i> , <i>Pseudomonas</i> , and other enterobacteriaceae, clostridial spp., <i>Bacteroides/Prevotella</i> spp.	3.375 g IV q6h
Imipenem	Enterococcal spp., streptococcal spp., <i>Staphylococcus</i> ,* <i>E coli</i> , <i>Pseudomonas</i> , and other enterobacteriaceae, clostridial spp., <i>Bacteroides/Prevotella</i> spp.	1 g IV q6h
Cefazolin	Staphylococcal spp.,* streptococcal spp., <i>E coli</i> , <i>Klebsiella</i> , <i>Proteus</i>	2 g IV q8h
Cefoxitin	Staphylococcal spp.,* streptococcal spp., <i>E coli</i> and similar enterobacteriaceae, clostridial spp., <i>Bacteroides/Prevotella</i> spp.	1–2 g IV q6h
Ceftazidime	Streptococcal spp., <i>E coli</i> , <i>Pseudomonas</i> , and other enterobacteriaceae	2.0 g IV q8h
Ceftriaxone	Streptococcal spp., staphylococcal spp.,* <i>Neisseria</i> spp., <i>E coli</i> , and most enterobacteriaceae (NOT <i>Pseudomonas</i> ), clostridial spp.	1 g qd
Ciprofloxacin	<i>E coli</i> , <i>Pseudomonas</i> , and other enterobacteriaceae	400 mg q12h
Gentamicin	<i>E coli</i> , <i>Pseudomonas</i> , and other enterobacteriaceae	5–7 mg/kg qd (based on once-daily dosing strategy and no renal impairment)
Vancomycin	Streptococcal, enterococcal, and staphylococcal spp. (including MRSA, not VRE) q12h	15 mg/kg q12h
Erythromycin	Streptococcal spp., clostridial spp.	0.5–1.0 g q6h
Clindamycin	<i>Streptococcus</i> spp., <i>Staphylococcus</i> spp.,* clostridial spp., <i>Bacteroides</i> , and <i>Prevotella</i> spp.	900 mg q8h
Metronidazole	Clostridial spp., <i>Bacteroides</i> , and <i>Prevotella</i> spp.	500 mg q6h

MRSA: methicillin-resistant *Staphylococcus aureus*; spp.: species; VRE: vancomycin-resistant enterococci.

**NOTE: Dosage and dosage intervals are average recommendations. Individual dosing may vary.**

\*Not MRSA.



Suitable antibiotic regimens include the following:

- Imipenem, 1 g IV q6h.
- Piperacillin and clavulanate (Zosyn), 3.375 g q6h; or ceftazidime, 2.0 g q8h; or cefepime, 2.0 g q12h; **plus** gentamicin, 5–7 mg/kg qd. (based on a once-daily dosing strategy and no renal impairment); or ciprofloxacin, 400 mg q12h.
- Addition of vancomycin, 15 mg/kg q12h, if methicillin-resistant *Staphylococcus aureus* is a likely pathogen.
- Addition of linezolid, 600 mg q12h, if vancomycin-resistant enterococcus is a likely pathogen.

Battlefield casualties are at high risk for infection. In particular, war wounds are predisposed to infection due to environmental conditions on the battlefield, devitalized tissue, and foreign bodies. The key to minimizing wound infection is prompt and adequate exploration and debridement of devitalized tissue and removal of all foreign material. All wounds, including amputations, should be left open. Antibiotics are an adjunct to the prophylaxis of wound infections in the tactical setting. Knowledge of likely pathogens for particular infections and sites, as well as optimal antibiotics to eradicate those pathogens (Table 10-3), will aid the battlefield clinician in averting and treating infections.

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