

Prevention of Infections Associated With Combat-Related Eye, Maxillofacial, and Neck Injuries

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Abstract: The percentage of combat wounds involving the eyes, maxillofacial, and neck regions reported in the literature is increasing, representing 36% of all combat-related injuries at the start of the Iraq War. Recent meta-analysis of 21st century eye, maxillofacial, and neck injuries described combat injury incidences of 8% to 20% for the face, 2% to 11% for the neck, and 0.5% to 13% for the eye and periocular structures. This article reviews recent data from military and civilian studies to support evidence-based recommendations for the prevention of infections associated with combat-related eye, maxillofacial, and neck injuries. The major emphasis of this review is on recent developments in surgical practice as new antimicrobial studies were not performed. Further studies of bacterial infection epidemiology and postinjury antimicrobial use in combat-related injuries to the eyes, maxillofacial, and neck region are needed to improve evidence-based medicine recommendations. This evidence-based medicine review was produced to support the *Guidelines for the Prevention of Infections associated with Combat-related Injuries: 2011 Update* contained in this supplement of *Journal of Trauma*.

Key Words: War, Trauma, Head, Face.

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Combat operations in Iraq and Afghanistan have continued since guidelines were released for prophylaxis and treatment of combat-related eye, maxillofacial, and neck (EMFN) injuries in 2008.¹ Recent studies indicate that EMFN injuries comprised 36.2% of all injuries at the onset of the Iraq war,² although larger studies showed a slightly lower rate of 29% to 30%.^{3,4} A meta-analysis of all studies from the 21st century⁵ found incidence of injury to the face between 8% and

20%,^{3,6–10} the neck between 2% and 11%,^{3,6,7,9,10} and the eye between 0.5% and 13%.^{3,7,11} Further data on eye injuries alone show approximately a 6% incidence, down from the first Gulf war rate of 13% but consistent with the Israeli Defense Forces experience in the 1960s and 1970s.¹² Regardless, EMFN injuries now far exceed those reported from any previous conflicts. Whether this is a consequence of changes in defensive posture (e.g., body armor deployment and use of armored transportation), shifts in enemy tactics and weaponry, or the urban battlefield remains unclear (although the urban war in Somalia experienced a 12% EMFN injury rate).¹³ This article reviews recent developments in epidemiology, postinjury antimicrobials, and surgical techniques to prevent infection of EMFN injuries sustained in combat.

EPIDEMIOLOGY/MICROBIOLOGY OF WOUND COLONIZATION/INFECTION

Maxillofacial and Neck Injuries

We have previously noted that the EMFN infection wound rate from the Vietnam War was 7% to 42%.^{14,15} In the Balkans, conflict wounds became infected postoperatively in 19% of war-wounded patients,¹⁶ and in the Iran-Iraq war, 11% of maxillofacial injuries were complicated by infection.¹⁷ Two small case series from the Iraq war of patients undergoing open reduction and internal fixation of fractures at Role 3 (e.g., combat support hospital) described a 0% infection rate among 17 patients;¹⁸ however, a second review of 130 patients described a 24% infection rate.¹⁹

Actual pathogen descriptions of maxillofacial infections in combat-associated wounds are limited and include *Klebsiella* spp., and fungi (likely *Candida* spp.);²⁰ *Pseudomonas* spp., *Staphylococcus aureus*, and *Escherichia coli*;^{20,21} *Proteus mirabilis*, *Bacteroides fragilis*, *Peptococcus* spp., and *Peptostreptococcus* spp.;²¹ and *E. coli* and *Streptococcus pyogenes*.¹⁶ Unfortunately, infection rates are not reported so it is not clear if these reported microbes represent true infection or just colonization. Since our last review, no new studies from current conflicts have described bacterial epidemiology of infection following maxillofacial trauma. One study described a 7-year retrospective review of 38 patients with facial gunshot wounds, reporting a 10.5% infection rate, but pathogens were not described nor were locations or causes of infection or how they were treated.²² Postinjury antimicrobials with broad activity against the 12 previously described pathogens to prevent perioperative infections might

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TABLE 1. Suggested Antimicrobials and Duration of Administration for Postinjury Use in Maxillofacial and Neck Combat-Related Injuries

Agent	Dose and Schedule	Duration of Therapy	Evidence Base	Comments
β -lactam tolerant: cefazolin	2 g IV every 6–8 h	Postinjury and then for 24 h following initial surgical management	Strong recommendation, low-quality evidence	Preferred regimen, recommendation based on contaminated H&N oncology and open fracture data, however
β -lactam allergic: clindamycin	600 mg IV every 8 h	Postinjury and then for 24 h following initial surgical management	Strong recommendation, low-quality evidence	Acceptable alternative to cefazolin

IV, intravenously; H&N, head and neck.

be warranted; however, the evidence remains very poor and further studies are needed.

Eye Injuries

Despite the historical risk of endophthalmitis with intraocular foreign bodies (IOFBs), Role 5 (i.e., fixed hospital in home nation) data from Walter Reed Army Medical Center reveal only one definite case of endophthalmitis since 2001 with more than 100 eyes sustaining IOFB injuries (Dr. Marcus Colyer, personal communication). Infections in tissues surrounding the eye demonstrate a similarly low rate of infection (Dr. Marcus Colyer, personal communication). No cases of bacterial corneal infections have been reported following trauma, while three eyes have suffered fungal keratitis following penetrating eye injuries (less than 1% incidence). Preseptal, orbital, and adnexal infection rates have similarly remained low.

METHODS

A literature search was conducted using health technology assessment resources, including, PubMed, Embase, and DTIC. The search was limited to English-language articles that were published between January 1, 2006, and November 30, 2010. Five independent reviewers screened articles using predefined criteria.

POSTINJURY ANTIMICROBIALS

Maxillofacial and Neck Injuries

Antibiotic prophylaxis for war injuries has been described using “cephalosporins” and continuing them for at least 3 days postoperatively with some success.²¹ Perioperative ampicillin or penicillin¹⁷ have also been used. We previously concluded these agents might have utility. However, the duration of therapy, the definition of infection, and the organisms encountered are not defined, and the evidence to support antibiotic prophylaxis use is poor. Perioperative antibiotics are clearly still needed for traumatic war wounds of the maxillofacial region as they present contaminated with oral secretions and environmental debris. A recent extensive review of antibiotics for facial trauma recommended limiting prophylaxis to patients who have gross wound contamination, open fractures, joint involvement, or require delayed wound closure; to patients who are immunocompromised or at high risk for endocarditis; and to patients having gunshot wounds or penetrating injuries from military weaponry.²³ Studies

show reductions in contaminated surgery infection rates from 28% to 87% down to 6% to 20% using perioperative antibiotics, but these studies did not include trauma populations.¹ Suggested prophylactic agents (postinjury antimicrobial therapy) are included in Table 1.

The optimal duration of perioperative coverage for contaminated combat trauma wounds remains undefined in the literature based on recent publications. In our last review, we concluded that data from contaminated major head and neck cancer surgery might be applicable to traumatic injuries because the majority of infections are polymicrobial in both settings, as are other factors such as impaired vascular flow, large tissue defects, etc.^{1,24} A prospective randomized placebo-controlled multicenter trial of 1 day versus 5 days of antibiotics in this population showed 19% of patients infected with 1 day of coverage versus 25% with 5 days (not significant).²⁴ This study provides robust evidence that extending perioperative prophylaxis past 24 hours does not reduce infection rates and is probably unnecessary in maxillofacial and neck trauma surgery. Maxillofacial fractures result from trauma, and while not equivalent to combat injuries, also often become infected and require fixative surgery. Therefore, studies in this area might also help define optimal use of prophylactic antibiotics for war injuries. A recent systematic review of prophylactic antibiotics for facial fractures analyzed four studies of good quality.²⁵ The authors found that short-term prophylactic antibiotics in one study resulted in a fourfold reduction in infections²⁶ and calculated a threefold decrease in the infection rate when all four studies are combined.²⁵ This evidence supports continued use of perioperative antibiotics when conducting repair of maxillofacial fractures and suggests surgical debridement alone is inadequate. Furthermore, the systematic review concluded use of 1 day or one dose of antimicrobials was as effective as longer courses. Zygoma, maxilla, and condyle injuries did not become infected, whereas the mandible injuries did (29%), and the authors’ final guidance was for short-term antibiotics for compound mandibular fractures and none for zygoma, maxilla, and condylar injuries. Caution is required in extrapolating these results to combat injuries; however, in these data, which represent only 1 study, the numbers are small and no high-velocity gunshots were analyzed.

A recent retrospective review of prophylactic antibiotics for zygomatic fractures from three civilian centers might be applicable to combat wounds; however, no gunshots were

included.²⁷ The authors studied 134 patients and used a protocol of no antibiotics if reduction was performed without plating; oral amoxicillin/clavulanate or cefuroxime or an ampicillin/dicloxacillin combination preoperatively and for two doses postoperatively if extra-oral reduction with plating was required; and the same regimen plus metronidazole if intraoral reduction with plating was required. This approach resulted in a 2% infection rate (higher than the previously quoted 0%), all in the intraoral fixation group. Notably, both infected patients did not receive metronidazole despite it being on their protocol. These studies suggest that shorter courses of antibiotics might be useful in combat injuries of the zygoma requiring fixation and that anaerobic coverage is important when the oral mucosa is involved. These conclusions are derived from experience with noncombat wounds and further studies are needed.

In summary, based on these recent^{25,27} and previously reviewed studies^{26,28,29} from mandibular fractures and contaminated head and neck cases²⁴ with similar outcomes, antibiotics in excess of those administered during the 24-hour perioperative period for maxillofacial injury do not appear to reduce wound infection (Table 1) and should be discontinued at 24 hours postoperatively.

Eye Injuries

Since 2001, endophthalmitis rates remain unusually low following combat ocular trauma. This has been attributed to the immediacy of globe repair and the universal administration of broad-spectrum prophylactic antibiotics. A prospective randomized study from Iran showed a statistically significant reduction in posttraumatic endophthalmitis rates when intraocular antibiotics were administered at the time of injury (2.3% vs. 0.3%).³⁰ Given the historical concern regarding the injection of intraocular antimicrobials (particularly gentamicin) in uninfected eyes, this route of administration is not currently recommended as the standard of care.³¹ Instead, in select cases of extreme intraocular contamination, their use is at the treating ophthalmologist's discretion. Current treatment patterns dictate the initiation of a fourth-generation oral and topical fluoroquinolone (Table 2) for the prevention of ocular infection. Data from the 1980s suggested that systemic antimicrobials have no role in the prevention or treatment of endophthalmitis.³² However, newer antimicrobials may provide improved intraocular penetration and are currently recommended in oral or intravenous routes in all cases of

penetrating ocular trauma.^{33,34} Suggested postinjury antimicrobial agents are included in Table 2.

DEBRIDEMENT AND IRRIGATION

Maxillofacial and Neck Injuries

There are no new studies in this area; however, acute management of most routine maxillofacial injuries should include wound debridement, primary closure, anatomic reduction, stabilization, and fixation of fractures. This is believed to result in an acceptably low rate of infection and return of form and function.^{35,36}

Eye Injuries

Irrigation and debridement of the eye in the field (i.e., Role 1 "buddy care") or at Role 2 (e.g., Forward Resuscitative Surgical System) facilities are discouraged. The eye should be protected with a rigid eye ("Fox") shield by field medical teams, and early primary closure of wounds (within 6–8 hours) with careful wound debridement and placement of perioperative prophylactic subconjunctival antibiotics by an ophthalmologist at Role 3 is preferred.

Although more study is necessary to examine whether topical agents are effective, no further studies have presented themselves since our last review, therefore we maintain our conclusion that early globe closure with cleansing of wounds using irrigation and conservative debridement of devitalized tissue reduces foreign bodies and the bacterial load that contributes to postoperative infection. The recommended irrigation solution is balanced salt solution, but the most effective irrigation solution remains unclear.

SURGICAL WOUND MANAGEMENT

Maxillofacial and Neck Injuries

In our previous review,¹ a low infection rate for maxillofacial and neck injuries overall was attributed to aggressive debridement, irrigation of wounds, meticulous removal of contaminants, minimal introduction of foreign synthetic material during initial surgery, coverage of bone with tension-free closure when possible, and immediate institution of antibiotics in high-risk wounds. Management paradigms for maxillofacial and neck injuries have evolved over the last 50 years, and while the basic principles of wound management as outlined above generally apply to all sites in the head and

TABLE 2. Suggested Antimicrobials and Duration of Administration for Postinjury Use in Eye Combat-Related Injuries

Agent	Dose and Schedule	Duration of Therapy	Evidence Base	Comments
Penetrating injury: β -lactam tolerant or allergic—levofloxacin	500 mg PO or IV daily	Postinjury and then for 7 d postoperatively or until retinal evaluation	Strong recommendation, low-quality evidence	Preferred regimen, recommendation based on retrospective trauma data and nontrauma studies of ocular penetration
Eye injury: burn or abrasion—erythromycin or bacitracin ophthalmic ointment, or fluoroquinolone ophthalmic solution	Topical: QID and PRN for symptomatic relief 1 drop QID	Until epithelium healed (no fluorescein staining)	Strong recommendation, low-quality evidence	

PO, orally; IV, intravenously; QID, 4 times daily; PRN, as needed.

neck, there remain some important differences based on the location of the skeletal injury and status of the soft tissue envelope.^{35–37}

Facial Injuries

There is little controversy over the acute management of most routine maxillofacial injuries: postinjury antimicrobials, wound debridement, primary closure, anatomic reduction, stabilization, and fixation of fractures will result in an acceptably low rate of infection and return of form and function.^{35–37} It is also accepted that for more significant high-energy trauma, early and conservative debridement, irrigation, fixation and immobilization, and primary closure with drainage are important to prevent infection.³⁸ However, there is no consensus regarding the optimal management of high-velocity injuries that result in severely comminuted mandibular fractures, either with or without composite tissue loss.

Some authors advocate closed reduction and delayed reconstruction as the preferred approach to the management of highly comminuted and avulsive mandibular fractures to prevent infection.³⁹ It appears that the loss of mucosal lining and difficulty in achieving a watertight intraoral soft tissue closure are associated with a high failure rate of primary mandibular bone grafts. Thus, grossly contaminated, avulsive defects of the mandible have been managed by stabilization of existing bone fragments, primary soft tissue closure, serial debridements, and a delay of bone reconstruction for at least 8 weeks.

The problem with this approach is that by delaying the restoration of ideal skeletal contours, projection, and symmetry, scar contracture occurs, and secondary reconstruction is compromised by an inelastic and hypovascular wound bed. To overcome these problems, some authors have advocated “temporary” wound coverage techniques and deferral of lengthy definitive procedures to a time when the patient has stabilized.⁴⁰ Other authors have proposed that severe facial trauma requires early tissue debridement and composite free tissue transfer to minimize scar contracture.⁴¹ Indeed, a small study of immediate fixation versus delayed showed a 7% versus 43% infection rate.¹⁹ Early reconstruction using microvascular free flaps facilitates early mucosal wound closure and could thereby decrease risk of delayed infection or fistula formation, but requires a commitment of significant resources and skills that may not be readily available at Role 3 facilities.

Regardless of the reconstruction method used, maxillofacial and neck wound beds will often require a period of intensive wound care before definitive restoration of form and function. Byrnside et al.⁴² reported their use of negative pressure wound therapy (NPWT) for wounds of the head and neck to facilitate formation of soft tissue granulation and promote closure of challenging soft tissue defects. Their study does not present statistically significant conclusions, but is notable for introducing the “wound vac” (NPWT) for use in head and neck wounds and recognizing its potential to decrease the incidence of wound infections and affect outcomes. NPWT might have a role in prevention of infections of the maxillofacial and neck region, but the complex topography might make its application to the face difficult.

Neck Injuries

Recent changes in the evaluation and surgical management of combat wounds of the neck may affect subsequent infection rates. Imaging technology advancements, particularly computed tomographic angiography (CTA), are altering the management of patients with penetrating neck injuries. Helical and multislice CTA has emerged as a fast, minimally invasive study to evaluate penetrating neck injuries.^{43–45} CTA is readily available in most trauma centers and Role 3 deployed hospitals, it allows accurate evaluation of the vascular and extravascular soft tissues and bones in less than 3 minutes, and it does not require the support of additional nonphysician staff. Direct and indirect signs of vascular injury are well demonstrated, as are signs of violation of the aerodigestive tract, neurologic injury, and bony fracture.

Although some centers still practice routine exploration for all neck injuries penetrating the platysma, many civilian centers in the United States have adopted a policy of selective exploration based on clinical and radiographic examination.^{46,47} In a retrospective study of 65 patients (47% gunshot wounds) seen at a civilian trauma center between 2000 and 2005 with neck wounds that penetrated the platysma, Bell et al.^{48,49} found that increased use of CTA in hemodynamically stable patients was associated with a decreased frequency of neck exploration and a “virtual elimination of negative neck exploration” The surgical approaches described were standard. However, data on antimicrobial or surgical drain use, length of follow-up, or detailed patient outcomes were not provided. No comparison between operated and observed patient outcomes was included, but the authors concluded that selective surgical intervention for these injuries resulted in minimal morbidity (including a low 3% infection rate) and mortality at their institution. While no patients with combat wounds were included in this trial, almost half were gunshot victims, and we concur with recommendations that CTA be considered in early management of combat wounds to the neck. Further study is indicated to determine the effect of reducing exploratory surgery on infectious complications.

When upper aerodigestive tract injury is suspected, diagnostic workup should be expeditious as management delayed by more than 24 hours increases morbidity and mortality.⁵⁰ Delay in diagnosis of esophageal perforation is a particularly important predictor of infectious complications. When an esophageal injury is found early, surgical management should include copious wound irrigation, cautious debridement, a two-layer closure, and adequate drainage. After repair of the mucosal perforation, a muscle flap should be placed over the esophageal suture line for further protection. If an extensive esophageal injury is present, a lateral cervical esophagostomy should be created and definitive repair performed later.

If suspicion of a pharyngeal perforation remains despite being unconfirmed by examination or exploration, the casualty should have nothing by mouth, be observed for 7 days, and a swallow study should be repeated before advancing the diet. Fever, tachycardia, or widening of the mediastinum on serial chest radiographs or computed tomography indicates the need for repeat endoscopy or neck exploration.

Eye Injuries

Ocular injuries remain unique with regard to prevention and treatment of infection insofar as the majority of the eye is avascular and has limited capability to counter the presence of even a small bacterial load. Risk factors for the development of endophthalmitis include delayed primary closure, presence of IOFB, violation of the lens capsule, and wound contamination.⁵¹ Thus, treatment paradigms have evolved during the current conflict to emphasize immediate protection of the eye with a Fox Shield by field medical teams, early primary closure of wounds (within 6–8 hours) with careful wound debridement and placement of perioperative prophylactic subconjunctival antimicrobials at Role 3.³⁴ Given the low infection rate, the need to urgently evacuate patients to Role 4 (e.g., fixed hospital out of combat theater of operations) and Role 5 has superseded the urgency of IOFB removal with the known surgical complexities of vitreoretinal intervention in an austere environment.

Aggressive debridement of lid wounds with reapproximation of margins and placement of nasolacrimal stents have been the mainstay in the surgical management of periocular wounds and likely accounts for low rate of extraocular infections and should be the standard of care.^{52,53}

UNRESOLVED ISSUES/RESEARCH GAPS

Since publication of the last guidelines in 2008, no new epidemiologic studies of bacterial etiologies or antimicrobials used have been published for infections following eye, maxillofacial, or neck trauma. These studies, if performed, would be helpful in formulating better guidance for empiric antimicrobial coverage following injury and assessing best practices of antimicrobial use. What can be said is that ocular infections remain extremely rare and that current practice of eye injury management throughout all roles of care should continue. The limited reports of pathogens isolated in the Vietnam, Lebanese, and Balkans conflicts indicate that these data are collectable. We encourage military and civilian clinicians who manage gunshot wounds and blast injuries to undertake, at a minimum, retrospective studies of bacterial epidemiology and antimicrobial usage in comparison with outcomes using existing databases and records.

Recent changes in surgical technique include a debate over whether outcomes are improved in delayed versus immediate reconstruction. Based on one study, CTA appears to reduce unnecessary neck exploration and subsequent infection and therefore should be strongly considered as part of initial management of penetrating neck trauma.

No new randomized controlled trials for postinjury antimicrobial prophylaxis of craniomaxillofacial trauma have been published since our last review. Several publications in the facial fracture literature (which includes trauma patients who often develop infection), while not equivalent to combat injury, seem to reinforce what has been learned in contaminated head and neck surgery. Longer periods of postoperative antimicrobials do not appear better than shorter regimens in preventing postoperative infections. Therefore, we continue to recommend stopping postinjury antimicrobial therapy 24 hours after initial surgical management.

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