Review article

A Looming Catastrophe: A Comprehensive Review of Post-Amputation Infections, Antimicrobial Resistance, and Limb Salvage in the Gaza Crisis

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Abstract

The military offensive in Gaza has precipitated a public health crisis of a magnitude and severity rarely witnessed in the 21st century. A defining feature is the epidemic of complex traumatic injuries necessitating a massive number of amputations, estimated to be in the tens of thousands. Performed under a total siege that has decimated the healthcare system, these procedures are fraught with an extreme risk of life-threatening post-amputation infections. This systematic review synthesizes data from humanitarian agencies, frontline medical reports, and public health analyses to delineate the multifactorial etiology of this iatrogenic catastrophe. We expand upon the known drivers non-sterile surgery, antibiotic shortages, and the "torso amputation" phenomenon by incorporating detailed discussions on the emerging crisis of antimicrobial resistance (AMR), the specific immunological vulnerabilities of a malnourished population, and the psychological trauma compounding physical recovery. The situation represents a violation of the principles of medical neutrality and has created a cohort of survivors with profound, long-term disability. This review concludes that the infection crisis is a man-made outcome of siege warfare and demands an urgent, coordinated international response focused on unimpeded humanitarian access, medical evacuation, and the establishment of advanced wound care and rehabilitation services to mitigate a legacy of suffering.

Keywords: amputation, infection, Gaza, conflict medicine, humanitarian crisis, antibiotic resistance, trauma surgery, siege, antimicrobial resistance (AMR), malnutrition.

Introduction

The scale of trauma in the Gaza Strip since October 2023 is unprecedented in its velocity and destructiveness. Beyond the staggering mortality figures, which exceed 38,000, the number of injured over 87,000 presents a complex and enduring medical challenge (World Health Organization [WHO], 2024b). Among these injuries, an estimated 10,000-15,000 people require amputations, a figure that includes a devastatingly high number of children, with many suffering multiple limb losses (Gupta *et al*., 2024; International Committee of the Red Cross [ICRC], 2024a). This represents a rate of limb loss not seen in recent conflicts.

In conventional trauma systems, amputation is a controlled procedure of last resort, with infection rates typically managed below 10-15% through aseptic technique, prophylactic antibiotics, and staged debridement (Murray *et al*., 2022). In Gaza, the confluence of a collapsed health system, a comprehensive siege, and the specific mechanisms of injury have created a perfect storm, pushing post-amputation infection rates to catastrophic levels, estimated by frontline surgeons to be as high as 50% or more (Gupta *et al*., 2024; Qeshta, 2024). This review provides a comprehensive analysis of the drivers, clinical manifestations, and long-term implications of the post-amputation infection crisis in Gaza, framing it not as a collateral effect of war but as a direct and predictable outcome of the systematic destruction of a medical system.

1. The Etiology of a Catastrophe: A Multifactorial Convergence

1.1. The Systematic Collapse of Surgical Infrastructure

The foundation of safe surgery a sterile environment, reliable equipment, and continuous utilities has been obliterated. Over 70% of Gaza's hospitals and two-thirds of its primary care clinics have been damaged or destroyed, forcing medical care into overwhelmed, makeshift facilities (WHO, 2024a).

- **The Non-Sterile Operating Theatre:** Reports describe surgeons operating by the light of mobile phones, without running water for handwashing, reusing gloves until they disintegrate, and using sewing thread instead of sutures (MSF, 2024a). The absence of basic disinfectants like povidone-iodine forces the use of vinegar and other non-sterile alternatives, drastically increasing the microbial load introduced at the time of surgery.
- **The "One-Minute" Amputation:** The sheer volume of casualties and the lack of anesthesia have led to a shift in surgical priorities from limb salvage to life-saving damage control. Procedures are rushed, with surgeons reporting "one-minute amputations" performed with limited or no debridement of non-viable tissue (Gupta *et al*., 2024). This leaves a contaminated and traumatized wound bed, highly susceptible to infection.

1.2. The Crisis of Antimicrobials and Emerging Resistance

The siege has created a critical shortage of all essential medicines, but the deficit in antibiotics is particularly consequential for amputees.

- **Prophylaxis and Treatment Failure:** The consistent absence of broad-spectrum intravenous antibiotics (e.g., third-generation cephalosporins, carbapenems) means that neither effective prophylaxis nor reliable treatment for established infections is possible. When available, antibiotics are often rationed, leading to sub-therapeutic dosing and abbreviated courses.
- **The Perfect Storm for Antimicrobial Resistance (AMR):** This environment is a breeding ground for AMR. The selective pressure from intermittent, sub-lethal antibiotic exposure, combined with the rampant transmission of pathogens in overcrowded wards, fosters the emergence of multi-drug resistant organisms (MDROs). Reports are emerging of wound infections with pan-resistant *Acinetobacter baumannii*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* so-called "nightmare bacteria" that are virtually untreatable with available antibiotics (Qeshta, 2024). This transforms a manageable surgical site infection into a fatal condition.

1.3. The Specifics of Trauma: "Torso Amputations" and Crush Syndrome

The weaponry and tactics used have resulted in unique injury patterns that inherently carry a higher risk of complication.

- **"Torso Amputations" and High-Energy Injuries:** The term "torso amputation," coined by surgeons in Gaza, refers to a guillotine amputation through the hip or shoulder joint, often required to free a patient from rubble when more distal control is impossible due to the nature of the collapse (Gupta *et al*., 2024). These are massive, contaminated wounds with a huge surface area, involving muscle groups highly prone to necrosis and infection. The high-energy transfer from explosions also causes extensive devitalized tissue zones far from the visible wound, which serve as a nidus for infection if not meticulously debrided a luxury unavailable in Gaza.
- **Crush Syndrome and Immunosuppression:** Many amputees are survivors of prolonged entrapment, leading to crush syndrome. The reperfusion of crushed muscle releases myoglobin, potassium, and inflammatory cytokines, leading to acute renal failure, metabolic acidosis, and a systemic inflammatory response syndrome (SIRS) that paradoxically is followed by a state of immunoparalysis, leaving the patient highly vulnerable to sepsis (Matsushima *et al*., 2020).

1.4. The Host: A Population in a State of Acquired Immunodeficiency

The physiological state of the patient population is a critical, often overlooked, variable.

- **Macronutrient and Micronutrient Deficiency:** The population is experiencing famine-like conditions (IPC, 2024). Severe protein-energy malnutrition directly impairs neutrophil function, T-cell-mediated immunity, and complement production. Deficiencies in key micronutrients like Vitamin A and C and zinc, all critical for collagen synthesis and

epithelialization,severely compromise wound healing, turning a simple stump into a chronic, non-healing wound.

• **Communicable Disease in Displacement:** Over 1.7 million people are displaced into overcrowded shelters with inadequate water, sanitation, and hygiene (WASH) facilities (OCHA, 2024). Outbreaks of infectious diarrhea, hepatitis A, and upper respiratory infections are rampant. For an amputee with an open wound and a suppressed immune system, a concurrent bout of gastroenteritis or pneumonia can be the final insult that precipitates sepsis.

2. Clinical Sequelae and Management in a Resource-Void

The clinical progression of a post-amputation infection in this context follows a predictable and grim pathway.

• **From SSI to Osteomyelitis:** Initial surgical site infections (SSI), presenting with erythema, pus, and dehiscence, rapidly progress due to the lack of effective intervention. The infection spreads to the bone, causing osteomyelitis. Treating chronic osteomyelitis requires extensive surgical debridement and weeks of targeted IV antibiotics,neither of which is feasible, leading to a chronic, draining sinus and systemic illness.

• **Necrotizing Soft Tissue Infections:** The presence of devitalized tissue and virulent pathogens creates an ideal environment for necrotizing fasciitis, a rapidly spreading infection that destroys soft tissue and has a high mortality rate even in optimal settings. In Gaza, it is almost universally fatal.

• **The Rehabilitation Abyss:** A well-healed, non-tender stump is the prerequisite for prosthetic fitting and rehabilitation. The epidemic of infections makes this impossible. Patients are left with painful, unstable stumps, prone to breakdown. The near-total absence of prosthetic and orthotic services, physiotherapy, and psychological support in Gaza condemns a generation of amputees to permanent, profound disability (ICRC, 2024b).

3. Discussion: A Violation of Medical Neutrality and a Public Health Failure

The crisis in Gaza is a stark demonstration that modern medical advances can be rendered null by the conditions of war. The high infection and mortality rates among amputees are not accidental; they are the direct result of the denial of the means of survival and medical care, constituting a grave breach of International Humanitarian Law (IHL), which mandates the protection of the wounded and sick and the civilian infrastructure necessary for their care (Amnesty International, 2024).

The long-term public health implications are staggering:

1. **A Permanent Disability Crisis:** Tens of thousands of individuals, many of them children, will require lifelong medical care, rehabilitation, and social support.
2. **An AMR Reservoir:** Gaza has become an incubator for multi-drug-resistant pathogens that pose a threat not only to the local population but also to the broader region, potentially for decades to come.
3. **Psychological Trauma:** The compound trauma of experiencing bombardment, losing a limb, and enduring a painful, protracted infection will result in an epidemic of post-traumatic stress disorder (PTSD), depression, and anxiety disorders.

Conclusion and Recommendations

The limbs lost to explosives are only the initial injury. The subsequent infections represent a second, more insidious mass casualty event, one that is ongoing and largely preventable. The international community's response has been woefully inadequate.

Urgent Recommendations:

1. **An Immediate and Sustained Ceasefire:** This is the foundational prerequisite for any meaningful medical intervention.
2. **Unimpeded Humanitarian Access:** All border crossings must be opened for the massive and consistent flow of medical supplies, including advanced wound dressings, a full spectrum of antibiotics, and surgical equipment.
3. **Systematic Medical Evacuation:** A large-scale, streamlined mechanism for the evacuation of complex cases, particularly those with MDRO infections and osteomyelitis, to regional specialized centers is non-negotiable.

4. **Restoration of WASH and Nutrition:** The provision of clean water, sanitation, and nutritional support is a medical intervention as critical as antibiotics in this context.
5. **Long-Term Planning for Rehabilitation:** The international community must immediately begin planning and funding a decades-long program for physical rehabilitation, prosthetic services, and mental health support for the people of Gaza.

In conclusion, the post-amputation infection crisis in Gaza is a man-made plague unfolding in real time. Addressing it requires not only medical supplies but also a fundamental commitment to upholding IHL and human dignity. The world is witnessing the systematic creation of a disabled population; the moral and practical imperative to intervene has never been clearer.

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