

Bone and Soft Tissue Pathogens in War Trauma: Resistance Trends and Surgical Implications for Orthopedic and Traumatology Surgeons

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INTRODUCTION:

In every war, it's the orthopedic injuries that leave some of the deepest, most lasting marks, on patients and on the field of surgery itself. A century ago, open fractures on the muddy battlefields of World War I almost always meant amputation. Later, in Iraq and Afghanistan, U.S. surgeons faced a new kind of enemy: drug-resistant infections that clung to bone, metal, and flesh. *Acinetobacter baumannii*, nicknamed "Iraqibacter," became notorious for complicating even the most skilled reconstructions. It forced a hard lesson: saving a limb takes more than a clean cut and a good fixator, it takes understanding the microbes you're up against.

Now, Ukraine faces similar challenges. Tens of thousands of civilians and soldiers have sustained high-energy blast and ballistic injuries. Patients are medically evacuated through multiple facilities across the country before reaching tertiary centers, often presenting late, colonized, and heavily pre-treated. While broad resistance patterns in Ukraine have been documented, little is known about the site-specific microbiology of bone and soft tissue infections, the infections that most directly determine reconstructive success. This study analyzes orthopedic surgical isolates from war-wounded patients to identify dominant pathogens and resistance profiles that threaten limb salvage and hardware retention in Ukraine's modern battlefield hospitals.

METHODS:

A sub-analysis was conducted on diagnostic microbiology data collected between January 1, 2024, and December 31, 2024, at a major trauma and reconstructive surgery center in Western Ukraine. The analysis focused exclusively on isolates obtained from orthopedic-relevant infection sites, including bone, deep wounds, and post-operative surgical sites in patients treated for war-related injuries.

Data were extracted from the hospital's electronic microbiology system, and a site-specific cumulative antibiogram was developed in accordance with the Clinical and Laboratory Standards Institute (CLSI) M39-A4 guidelines. In line with these standards, only the first isolate per bacterial species per patient during the study period was included to prevent overrepresentation of repeat cultures. Bacterial species were reported only if ≥ 30 isolates were available to ensure statistical reliability.

Antimicrobial susceptibility testing (AST) was performed according to EUCAST methodology. The analysis focused on orthopedic-relevant pathogens:

- S. Aureus*: adheres to bone and implants, forms biofilms, induces chronic osteomyelitis
- Pseudomonas* spp.: Forms robust biofilms on grafts and metalwork; linked to chronic infections
- Acinetobacter* spp.: strong implication in war-related infections due to environmental persistence, multi-drug resistant strains penetrate deep bone
- *Klebsiella pneumoniae*: high rates of tissue invasion and antibiotic failure.

The resistance of these bacteria were compared with resistance rates from other stages in the trauma evacuation pathway, to highlight regional variation and potential impact of medical evacuations on antimicrobial resistance spread.

RESULTS:

After excluding duplicate patient samples, a total of 393 diagnostic isolates from the traumatology departments of the hospital union were analyzed. The most frequently identified pathogen was *Acinetobacter* spp. (n = 62), with notable resistance rates: 53% to meropenem and 86% to levofloxacin. *Staphylococcus aureus* was the second most prevalent organism (n = 54), of which 24% were methicillin-resistant (MRSA). *Klebsiella* spp. accounted for 44 isolates, demonstrating 71% resistance to meropenem and 84% to levofloxacin. *Pseudomonas aeruginosa* was isolated in 32 cases, with 25% resistance to meropenem and 50% to levofloxacin.

DISCUSSION AND CONCLUSION:

In this study of 393 diagnostic isolates from orthopedic patients in the traumatology departments of a major Ukrainian hospital union, we observed a high burden of multidrug-resistant organisms (MDROs), posing significant challenges for infection control and surgical success.

Compared to national surveillance data from Ukraine (2021), these figures represent a markedly higher burden of resistance in orthopedic infections. For example, *K. pneumoniae* carbapenem resistance was 71% in our cohort vs. 64% nationally, while *Acinetobacter* spp. resistance to meropenem was 53% in orthopedic patients, compared to only 37% in a Kyiv Hospital. Fluoroquinolone resistance in *P. aeruginosa* (50%) and *Klebsiella* spp. (84%) also far exceeded national and Kyiv benchmarks.

These findings reflect a concentrated resistance burden among orthopedic trauma patients, likely shaped by the trauma evacuation pathway. War-wounded individuals often undergo multiple interhospital transfers, typically from Eastern to Western Ukraine. During this process, patients are exposed to suboptimal infection control practices, repeated empirical antibiotic use, and delays in definitive surgical care. Each step in the evacuation chain presents an opportunity for colonization with MDROs, especially in open wounds or contaminated surgical sites.

From an orthopedic perspective, the clinical consequences are profound. These pathogens are directly associated with complications such as flap failure, non-union, osteomyelitis, and implant loss. The observed levels of resistance, particularly to levofloxacin and meropenem, undermine the effectiveness of standard surgical prophylaxis and necessitate tailored perioperative strategies based on current, site-specific susceptibility data.

Our findings underscore that trauma medevacs are not just logistical necessities but epidemiologic drivers of AMR. Orthopedic teams must integrate local microbiological trends into surgical decision-making and collaborate with infectious disease specialists to mitigate risk. Redesigning trauma pathways and strengthening antimicrobial stewardship along the evacuation chain may be key to preserving limb salvage outcomes and preventing avoidable surgical failure.