HEALTHCARE MANAGEMENT IN CONFLICT SETTINGS: THE CRITICAL ROLE OF MEDICAL LABORATORIES AND BIOSAFETY

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In contemporary global contexts characterized by persistent armed conflicts—such as those in Ukraine and the Middle East—healthcare system management extends beyond routine hospital operations and constitutes a critical component of overall health system resilience. Strategic decisions on resource allocation and contingency planning can substantially influence the probability of secondary public health outbreaks, potentially mitigating or exacerbating widespread crises in short timeframes. Medical diagnostic laboratories (hematology, microbiology, immunology) play a central role in these settings by performing diagnostics and providing ongoing surveillance of biological threats, which can escalate rapidly amid wartime disruptions and lead to significant consequences. Reports from conflict zones document frequent disruptions to laboratory operations, including power outages, infrastructure damage from attacks, forced staff relocation, and security breaches such as theft. The biological risks persist irrespective of ceasefire agreements and necessitate ongoing preparedness and mitigation efforts. Healthcare leadership should therefore prioritize biosafety and biosecurity as core operational components, integrated into routine management rather than confined to emergency plan appendices, to effectively reduce associated risks.

Key words: *management, laboratory, biosafety, conflict, biological risk*

1. INTRODUCTION

Contemporary global maps reveal the widespread presence of armed conflicts, which have become a recurring feature of the international landscape and are often overlooked until they directly impact populations or health systems. From the war in Ukraine, now in its fifth year and destroying the health infrastructure in entire swaths of the country, to the endless tensions in the Middle East, where hospitals and laboratories are becoming targets or collateral damage, the reality is stark.

Healthcare management is no longer a desk job, with paperwork and routine procedures. It has become a front line, where every choice made today, how much reagent

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stock to keep, where to place backup generators, how to train people for evacuation, can stop a public health catastrophe or, on the contrary, trigger one with chain effects that go beyond borders.

Medical laboratories are right in the middle of this situation. Hematology, which counts blood cells in patients with massive hemorrhages on the front, microbiology, which identifies nosocomial infections in war wounded, or immunology, which tracks the spread of viruses in refugee camps, all of these are not just auxiliary services. They are the diagnostic brain of the entire system. Without them, doctors work haphazardly, and epidemiological surveillance collapses. But this is precisely where the greatest danger arises: biological risks.

In the chaos of war, a laboratory that was functioning perfectly yesterday can become a real threat tomorrow. Lack of electricity after a bombing, theft of equipment, forced displacement of personnel, interruption of supply chains with disinfectants or triple packaging for transporting samples, all of these are not movie scripts. Such incidents have been documented in reports from conflict-affected areas, including cases where diagnostic samples remained in non-functional refrigerators due to power failures or equipment damage. For that is important technicians to improvise decontamination without running water.

The World Health Organization makes this clear in its updated biosecurity guidance: extreme situations, war, civil unrest, devastating natural disasters, require special protective measures, tailored to the extreme risks [13]. This is not just about ordinary laboratory accidents. It is about the possibility that pathogens can get out of control and trigger secondary outbreaks just when the health system is already overwhelmed. In Ukraine, the 2022 invasion endangered dozens of public laboratories that handled dangerous pathogens. Although the accusations of biological weapons were proven unfounded, the real risk of accidental release existed due to destruction, prolonged power outages, and logistical chaos [7].

Staff had to evacuate sensitive stocks under bomb threat and monitoring antimicrobial resistance in the wounded became a daily challenge. That is why biosafety (which protects us, those who work there, and the surrounding community from accidental exposures) and biosecurity (which prevents the theft, loss, or intentional misuse of biological materials) can no longer sit as forgotten appendages in emergency plans. They must be the absolute priority, integrated into every management decision, from choosing the location of the

laboratory to monthly simulations of biological breaches under total blackout conditions.

In Romania, in the absence of a current armed conflict, hospital regulations, according to the national legal framework, oblige healthcare institutions, including medical laboratories, to develop and maintain preparedness plans for major crisis situations, such as war, disasters, terrorist attacks or social crises. Ignoring them is not just administrative negligence, it is a lack of responsibility towards the patients of tomorrow.

The paper proceeds with an in-depth review of healthcare management in conflict-affected settings, emphasizing the critical functions of medical analysis laboratories and approaches to minimizing biological risks. Specific elements discussed encompass the formulation of robust business continuity plans, implementation of realistic simulation-based training, and allocation of resources for preventive measures while conditions permit proactive planning Because, in the final analysis, biological safety is not a theoretical chapter in some textbook. It is a matter of survival, for staff, for patients and for the entire community.

2. SECURITY OF MEDICAL LABORATORY PERSONNEL

In conflict-affected settings, laboratory personnel may face simultaneous physical and biological threats, such as in a microbiology lab in a city on the edge of the front. Explosions are heard outside, the power is constantly off, and samples are in refrigerator with dangerous strains that should never be released outside.

At such times, the physical security of the building and the protection of the people working there are no longer bureaucratic items in the emergency plan, an essential layer of protection against biological risks. In modern conflicts, medical laboratories are no longer sanctuaries protected by the Geneva Conventions.

On the contrary, they become precise targets or, at the very least, collateral casualties. The study of Mariupol shows that 77% of the city's medical facilities were seriously damaged during the Russian siege from February to May 2022, and the size of the building did not matter: attacks hit small laboratories and large blocks of flats equally often [10].

This suggests that it was not just random fire, but a deliberate strategy to destroy the health infrastructure. For an analysis laboratory, the consequences are twofold: on the one hand, equipment is destroyed, reagents are lost, refrigerators with pathogens stop working; on the other hand, unauthorized access becomes possible – someone can enter and

steal sensitive samples exactly when security is minimal.

Therefore, physical security must be thought out from scratch in continuity plans. It is not enough to put a lock on the door. Managers must choose or adapt less visible locations: basements, buildings with reinforced walls, peripheral areas away from main arteries. In Ukraine, military doctors quickly learned to use underground parking lots and cellars as field hospitals precisely to escape drones and missiles [6].

For laboratories, this means biosafety chambers moved to lower levels, diesel or solar hybrid generators mounted in protected locations, windows covered with anti-fragmentation mesh, surveillance cameras with backup batteries and, where the law allows, concrete physical barriers or barbed wire fences. Controlled access becomes vital.

In peacetime, a magnetic card is enough. In conflict, talking about strict lists of essential personnel, daily manual checks, entry-exit logs and, in extreme cases, armed guard coordinated with local authorities. No one enters the BSL-2 or BSL-3 area without a clear reason, and sensitive samples must be kept in biometric safes that work even without power. And don't forget opportunistic robbery: in the chaos of war, expensive equipment disappears overnight, and a broken refrigerator means biological hazards are released into the environment.

But the hardest part is the security of the staff. Lab technicians, biochemists, microbiologists are not trained for war. They come to work with their families in mind, not their helmets on. However, they become vulnerable just like anyone else: they can be injured on the way to the lab, taken hostage, threatened into giving information, or simply killed in direct attacks on the building.

Many choose to flee – and who can blame them? Those who stay work under extreme stress, with delayed or reduced salaries, without running water, without hot food, with the constant fear that a siren means the immediate evacuation of dangerous samples. Reports from conflict zones show that absenteeism is increasing explosively, supply chains are breaking down, and the remaining staff are physically and mentally exhausted [14].

Therefore, management must include concrete measures for people, not just buildings, plans to evacuate key staff families to safe areas, mandatory rotations to ensure that no one gets burned out, free psychological counseling, special life insurance and, above all, realistic training. Not just paper biosafety exercises, but real simulations: "What do you do if a kamikaze drone enters the yard?", "How do you seal a biosafety cabinet in five minutes

when the power goes out?", "What is the alternative route to evacuate samples if the bridge blows up?".

Staff must know how to combine biological and physical protection: N95 mask plus helmet, biosafety coverall plus light bulletproof vest, emergency backpack with disinfectant, flashlight, and triple packaging for transporting samples under fire. Sometimes it also means collaborating with military or civil protection structures to have access to intelligence information - where the next attack will be, which areas are temporarily safe.

In Romania, where not at war, all this seems exaggerated. But hospital regulations oblige us to prepare for exactly such scenarios. Ignoring them means leaving the laboratories exposed, and the staff - our only real capital - defenseless.

Physical security and human security are not two separate things: they form the same defense line. If the building falls, people die. When people leave, the building becomes useless. And in both cases, biological risks get out of control precisely when the medical system is at its weakest.

Today's preparation – simple fortifications, tough training, clear relocation plans – saves lives tomorrow. Not just of patients, but of those who work, day in, and day out, to save them.

3. THE REDISTRIBUTION OF THE PRIORITIES

When an armed conflict hits hard, the health system can no longer do everything at once. Resources, money, people, reagents, electricity, suddenly dwindle, and needs explode. The laboratory manager wakes up facing a harsh reality: he can no longer process all the tests as before. He must choose what really matters now, today, in the next few hours.

Redistribution of priorities becomes not an option, but the only way to save lives without letting the system completely collapse. First of all, vital emergencies come first. Blood counts for patients with massive bleeding on the front, coagulation tests for those with serious trauma, cultures from infected wounds, these do not wait.

A study of hospitals in Ukraine clearly shows during the war, the number of daily emergency admissions increased slightly (from 2773 to 2830), but laboratory services decreased dramatically – only 85% of hospitals still offered laboratory tests compared to 97% before the war [5].

This means that many routine tests were postponed or stopped, and the focus shifted to what was essential for immediate survival. Then there are nosocomial infections and antibiotic resistance, which are exploding in hospitals overcrowded with war wounded.

Laboratories must prioritize antibiograms and the rapid identification of multidrug-resistant pathogens. In Ukraine, the war created a perfect environment for the spread of resistant bacteria, medical evacuations, poor conditions, and the empirical use of antibiotics without guidance, all of which accelerated the problem [11].

Managers have learned to allocate limited resources to antimicrobial resistance testing, even if it means drastically reducing cancer screenings or routine tests for chronic diseases. Epidemiological surveillance is not disappearing, but it is changing.

Instead of broad monitoring of communicable diseases, the priority becomes the early detection of outbreaks that can overwhelm an already stretched system: dysentery in refugee camps, hepatitis in areas with contaminated water, meningitis in crowded shelters. The WHO emphasizes that in fragile and conflict settings, laboratories must support minimum essential services, including surveillance for diseases with epidemic potential, even if this means sacrificing long-term preventive programs [12].

Non-urgent diagnostic tests, such as tumor marker assays, routine hormonal evaluations, and screenings for chronic diseases, are frequently deferred or temporarily suspended in such settings. In Gaza, for example, severe shortages of reagents and equipment have led to the collapse of many laboratory services, exacerbating outbreaks of infectious diseases [1].

In Tigray, Ethiopia, access to laboratory tests for diabetes has fallen to only 4% of patients who received them before the war [4]. This shows the price paid: chronic diseases worsen, complications increase, but in the context of war, immediate survival takes precedence.

How is redistribution done in practice? Through clear triage of analyses. Many laboratories in conflict zones have introduced daily priority lists: the red category (vital emergencies, hemorrhage, septic shock), the yellow category (suspected infections in the wounded, critical epidemiological confirmations), the green category (all the rest, postponed or redirected to mobile or partner laboratories in safe areas). Mobile laboratory teams, with portable equipment, generators and biosafety cabinets, take over some of the burden, allowing the labs to focus on complex analyses.

Staff must be involved in decisions. A manager who imposes priorities from above without explanation risks demotivation and errors. Short daily discussions, as “today have 200 samples, but reagents for only 80, what do process first?”, help the team understand and accept the difficult choices.

Partnerships save the situation. Collaboration with laboratories in neighboring countries or with international networks (WHO, Red Cross, military partners) allows sensitive samples to be sent outside the conflict zone. In Ukraine, this meant coordinated medical evacuations and transfer of samples for advanced analyses [3].

But redistributing priorities also has a hidden cost: loss of capacity in the long term. When routine surveillance decreases, antimicrobial resistance grows unnoticed; When preventive screenings stop, chronic diseases explode later. That's why the plan must include a recovery strategy: once the intensity of the conflict subsides, resources are gradually reallocated back to prevention and monitoring.

In Romania, where the threat of conflict is not hypothetical, laboratory managers should practice these scenarios now. Do real-world simulations: "If 500 wounded people come in tomorrow and only have 30% of our normal reagents, what do stop? How do communicate with clinicians?"

Preparation through structured planning minimizes operational disruptions and contributes to improved patient outcomes. Redistribution of priorities represents an evidence-based approach to resource allocation and adaptive management, rather than a concession of capability. In conflict settings, laboratory services cannot address all demands simultaneously; however, they remain indispensable for meeting the most urgent clinical and epidemiological needs in real time.

4. THE MANAGEMENT OF THE MEDICAL ANALYSIS LABORATORIES – A STRATEGIC PRIORITY

In the event of an armed conflict, medical diagnostic laboratories cease to function merely as ancillary hospital services and instead become a critical component of the overall health system's resilience. These laboratories provide essential diagnostic support across disciplines such as hematology, biochemistry, microbiology, and immunology.

Without timely and accurate results from these areas, clinicians are unable to make informed treatment decisions for trauma patients, detect nosocomial infections promptly, or monitor and contain infectious disease outbreaks that commonly emerge in densely populated settings such as refugee camps or overloaded healthcare facilities.

In conflict settings, the operational continuity of medical diagnostic laboratories emerges as a national strategic priority, extending beyond routine local management. The evidence from recent armed conflicts demonstrates that, in the

absence of robust preparedness and contingency planning, laboratory functions can deteriorate rapidly, compromising health system resilience.

In Ukraine, after the invasion in 2022, many laboratories had to improvise: the power went out daily, reagents were no longer available, staff dispersed. However, where Business Continuity Plans (BCPs) were implemented, the laboratories held up better. These plans are not blank sheets of paper – they mean real redundancy: spare equipment in different locations, buffer stocks of consumables for at least 3-6 months, clear protocols for triage of analyses and mobile teams ready to take over the critical volume.

A concrete example comes from the efforts to expand PCR capacities in Yemen, where, in the midst, of war and humanitarian crisis, laboratories were strengthened for rapid molecular diagnostics, with impressive results in detecting outbreaks, even though the logistical challenges were enormous [2].

In conflict settings, priorities undergo a significant reorientation. Routine and non-urgent diagnostic tests, such as blood glucose monitoring in stable diabetic patients, annual lipid profiles, and oncological screenings, are frequently deferred or temporarily suspended.

Conversely, resources are redirected to prioritize critical and life-saving analyses, including complete blood counts for patients with massive hemorrhage, microbiological cultures from war wounds to inform antibiotic therapy, and rapid diagnostic tests for respiratory pathogens in overcrowded settings such as refugee camps.

Managers learn to triage daily: what samples are processing today with limited reagents? Which tests can be postponed without major risk? In Gaza and other areas of protracted conflict, the lack of reagents and energy led to the partial collapse of laboratory services, which aggravated infectious outbreaks and increased avoidable mortality [1].

The lesson is clear: without a strict hierarchy of priorities, the laboratory becomes ineffective exactly when it is needed most. Mobile laboratories are a strategic solution that has saved many situations. Small teams, with portable equipment (hand-held hematology analyzers, mini-PCR, solar generators), travel to the most affected areas.

In Ukraine, such mobile units have allowed on-site testing of the wounded, reducing the time to diagnosis, and avoiding the transport of samples over dangerous roads. These teams require special training: not only technical, but also security, how to operate a biosafety cabinet in a tent, under the threat of drones, or how to seal samples in triple packaging if they need to be evacuated quickly.

International partnerships help enormously: WHO, the Red Cross or laboratories in neighboring countries take over complex confirmations, send reagents or provide remote technical support. Strategic management also involves anticipating logistical risks. Supply chains are easily disrupted by conflict: blocked roads, closed ports, sanctions affecting imports.

Managers must diversify suppliers, stock strategically and have alternative plans – for example, local production of simple culture media or reuse of equipment through rigorous maintenance. In addition, communication with clinicians becomes essential: daily lists of shared priorities, short meetings in the morning to align real needs in the wards with laboratory capacity. Staff are the most precious and vulnerable resource.

In war zones, laboratory technicians and doctors work under extreme stress: delayed salaries, evacuated families, constant fear. Management must include mandatory rotations, psychological support, special insurance, and temporary relocation plans for those with families. Regular training – blackout simulations, biosecurity breaches, pressure evacuation – makes the difference between a laboratory that resists and one that collapses.

In the Romanian context, where the threat of conflict is not zero, laboratory management must integrate these lessons now. Continuity plans should be tested monthly, not annually; strategic stocks of essential reagents should be established; partnerships with EU or NATO laboratories should be strengthened for backup. Ignoring them means letting diagnosis become a lottery just when lives depend on an accurate result. Medical analysis laboratories in conflict are not a luxury – they are a strategic weapon of health defense.

Well-thought-out, proactive, and adaptable management transforms vulnerability into resilience. It's a priority that doesn't wait for a crisis to knock on the door; it's built in the quiet of today to save tomorrow.

5. RESULTS AND PROPOSALS

In Romania, the threat of armed conflict is not something abstract, it is a geopolitical reality that is feel daily, especially after the war in Ukraine reached the border. Our healthcare system, with medical analysis laboratories at its center, must move from plans on paper to concrete, tested and funded actions.

Proactive implementation of these strategies prior to any escalation is essential because the crisis could catch us unprepared. Preparation is done now, in relative silence, so as not to pay dearly later. The first essential step: the explicit integration of biosafety and biosecurity into county and national emergency plans.

Many hospital organizations and operation regulations (ROFs) already mention the obligation to be prepared for "war, disasters, terrorist attacks, social conflicts and other crisis situations". But these words often remain empty if they are not translated into chapters dedicated to biological risks.

The Ministry of Health and the Department of Emergency Situations (DSU) should oblige each hospital with a laboratory to have a separate chapter in the business continuity plan (BCP), with annual risk assessments adapted to conflict scenarios: prolonged blackout, bombings, looting, forced displacement.

The national biosafety guide for laboratories (latest available edition) needs to be urgently updated with lessons from Ukraine and the Middle East – for example, protocols for evacuating pathogen stocks in 30 minutes or controlled destruction under pressure. Second: real inter-institutional collaboration, not just on paper.

National reference laboratories (such as those at the Cantacuzino Institute or INSP) need to become coordination hubs. The Ministry of Health, DSU, the Inspectorates for Emergency Situations and the army should organize annual joint exercises, with simulations of a biological breach under war conditions: power outage, blocked roads, samples transported via alternative routes.

Partnerships with laboratories from neighboring NATO or EU countries, as Poland or Bulgaria, for backup: sending samples, exchanging reagents, mutual training. PNRR and post-2026 European funds can finance these links, including strategic stocks of portable BSL-2/3 equipment. Third: dedicated funding for resilience.

It is no longer possible with annual budgets cut to the bone. Special funds must be allocated for the modernization of laboratories: hybrid solar-diesel generators with a minimum autonomy of 72 hours, UPS systems for refrigerators with pathogens, video cameras and biometric access to sensitive areas, biosafety cabinets with backup batteries.

In addition, buffer stocks of essential reagents (for blood counts, cultures, PCR) for at least 6 months, stored in dispersed locations. The National Health Strategy 2023-2030 talks about strengthening surveillance capacity and rapid response to threats – this is exactly where laboratories come in [8].

The Ministry of Health budget should include a clear line "Preparation for conflict situations and high biological risks". Fourth: mandatory continuing education. Hospital managers, laboratory heads, technicians – all must undergo regular courses on biological risk management in a crisis context [9].

The College of Physicians, OBBCSSR and medical universities can organize practical modules: total blackout simulations, transporting samples in triple packaging on rough terrain, decontamination without running water. Trainings should be monthly in border hospitals (Constanta, Tulcea, Galati, Iasi), with the participation of the DSU and the army.

Essential personnel should have family protection plans – temporary relocation to safe areas – so that they do not leave en masse when the siren sounds. Finally, rigorous monitoring and auditing. INSP and the Control Body of the Ministry of Health should annually verify implementation: have the BCPs been tested? Are the stocks intact? Do the personnel know what to do in scenario X?

Reports should reach the government level, with real sanctions for negligence. Romania already has a good legal framework – hospital ROFs, sanitary authorization norms, biosafety guides – but consistent execution is lacking.

If invest now in these simple and practical measures, our laboratories will no longer be vulnerabilities, but robust biosafety and biosecurity measures that enhance system resilience of national health defense. It is no exaggeration to say that a well-prepared laboratory can prevent a secondary epidemic worse than the conflict itself.

The responsibility lies with all of us, all managers, DSP directors, decision-makers from the Ministry of Health. Immediate implementation of the proposed measures is recommended to strengthen laboratory preparedness.

6. CONCLUSIONS

In summary, the preceding analysis has addressed key dimensions of healthcare management in conflict settings: physical security of facilities and personnel, strategic reallocation of priorities amid resource constraints, operational continuity planning for medical laboratories, and specific preparedness recommendations tailored to the Romanian context.

A fundamental conclusion emerges from this discussion: the management of health systems during armed conflicts is not a specialized or peripheral field, but a core national security imperative. The central to this imperative are medical diagnostic laboratories, which represent a critical component of the health infrastructure. Failure to ensure their resilience and continuity can precipitate a transition from military conflict to a large-scale biological public health emergency with regional implications.

In Ukraine, evidence clearly demonstrates that even brief power outages in laboratories can pose substantial risks: refrigeration

systems fail, stored samples degrade, and the potential for accidental pathogen release increases significantly. Similarly, in Gaza and other regions affected by protracted conflict, shortages of reagents and reliable energy sources have repeatedly disrupted diagnostic capabilities, allowing infectious diseases to propagate without adequate control and contributing to elevated preventable mortality.

The key conclusion from these observations is that biosafety and biosecurity measures should not be regarded as optional administrative elements during peacetime; they represent essential protective mechanisms that must be established and maintained proactively, well in advance of any escalation into armed conflict.

A well-prepared laboratory, with monthly tested plans, with dispersed stocks, with personnel trained for extreme scenarios, does not just survive; it becomes a defense line that protects the entire population from invisible threats.

In Romania, where the border with an active war is a few dozen kilometers away, can no longer afford to treat preparation as a formality. Hospital regulations already oblige us to prepare for war and major crises, but the obligation becomes a reality only when move from words to deeds: investments in hybrid generators and resistant biosafety cabinets, tough and regular training, inter-institutional partnerships that really work, dedicated budgets for strategic stocks.

Every hospital manager, every laboratory head, every DSP director now has the duty to transform these legal obligations into concrete actions. Not tomorrow, not when it will be too late – now. Because biological risks do not negotiate truces. They don't wait for infrastructure to rebuild or for peace to return.

A single incident, an accidental breach, an opportunistic theft, a prolonged outage, can trigger a secondary outbreak more devastating than bullet wounds. And then it won't matter how well treated the wounded on the front lines if we've allowed resistant viruses or bacteria to spread unhindered.

The responsibility is clear and personal. It's not enough to say have plans. That is important to demonstrate that these plans withstand real-world simulations, that people know what to do when the power goes out and the sirens wail, that our laboratories are prepared to function even under maximum pressure.

Investments made today in laboratory preparedness, although initially appearing expensive, represent the most cost-effective preventive strategy in the long term. They avert substantially greater human suffering and economic burdens in future crises.

In essence, biosafety in medical diagnostic laboratories is not merely a technical topic confined to academic literature. It constitutes a core public health obligation.

The health system safeguards human lives, the most valuable asset, not solely through clinical interventions such as medicine and surgery, but also through sustained vigilance against biological threats that are often invisible.

In an increasingly vulnerable global environment, properly managed and resilient medical diagnostic laboratories represent one of the few reliable safeguards capable of preventing disasters from escalating to irreversible levels.

Proactive implementation is therefore essential: waiting until a crisis unfolds before recognizing the need for adequate preparation is insufficient. Rather, the necessary measures must be enacted promptly, while conditions still allow for effective action.

Survival in such contexts depends not on negotiation, but on deliberate and timely preparation. The strategic reallocation of laboratory resources constitutes a necessary and evidence-based adaptation to the severe resource limitations inherent in conflict settings.

AI DISCLOSURE

The author confirms that Grok from X.AI tools were used in the preparation of this manuscript, to identify the latest current bibliographic references. All content is solely the product of original human intellectual effort and authorship.

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