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Emergency Medical Services Readiness and Operational Response to Terrorism Threats within Health Security Frameworks-An Updated Review

Hind mohammed Alqahtani (1), Hind Mohammed Mujaddil Alqahtani (1), QASEM MOHAMMED KABSH (2), Saeed Shaya Abdullah Al-Dossary (3), Yousef Ali Huran Alanazi (4), Anwar Nawaf Alrashidi (5), Abdullah Madhyan Mubarak Al Mani (6), Mohammed Abdullah Mohammed Alwani (7), Ahmed Mania Ayed Alrashidi (8), Mastourah Nafea Muneer AL-Sehli (9), Mohammed Abdulrashid Abdulkarim Rajab (10), Fawaz Saleem Bunyadir Alotaibi (11)

(1) Al-Muzahmiya Health Center, Ministry of Health, Saudi Arabia,
(2) Primary Care Center in Higher Safety, Ministry of Health, Saudi Arabia,
(3) Riyadh First Health Cluster - Al-Sulayl General Hospital, Ministry of Health, Saudi Arabia,
(4) MCH hospital in Hafar Al-batin, Ministry of Health, Saudi Arabia,
(5) Hospital for long-term care, Ministry of Health, Saudi Arabia,
(6) Aflaj Hospital, Ministry of Health, Saudi Arabia,
(7) Jazan Health Cluster – Al-Harith General Hospital, Ministry of Health, Saudi Arabia,
(8) Khaybar General Hospital, Ministry of Health, Saudi Arabia,
(9) Al Madinah Al Munawwarah Hamra al-Asad Health Center, Ministry of Health, Saudi Arabia,
(10) Ministry of Health, Saudi Arabia,
(11) Umm Al-Doum General Hospital, Ministry of Health, Saudi Arabia

Abstract

Background: Terrorism continues to pose a significant global threat, with evolving tactics that increasingly target civilian populations and infrastructure. These incidents generate complex mass casualty scenarios that place extraordinary demands on Emergency Medical Services (EMS). In addition to conventional blast, firearm, and stabbing injuries, modern terrorism encompasses chemical, biological, radiological, and nuclear (CBRN) threats, requiring expanded preparedness within health security frameworks.

Aim: This review aims to examine the readiness and operational response of EMS to terrorism-related incidents, with a focus on injury patterns, responder safety, triage systems, interagency coordination, and the integration of tactical and CBRN response principles.

Methods: A narrative review approach was used, synthesizing existing literature and operational experiences related to terrorism incidents. The article analyzes patterns of injury from explosive, firearm, vehicular ramming, and CBRN attacks, while evaluating established EMS response models, scene zoning, triage protocols, and tactical medical frameworks.

Results: Terrorism-related incidents are associated with high injury severity, multidimensional trauma, and significant responder risk. Effective EMS response depends on scene security, structured zoning (hot, warm, and cold zones), rapid hemorrhage control, standardized triage protocols, and strong coordination with law enforcement and public health authorities. Tactical medical integration and specialized teams improve survivability while reducing responder harm.

Conclusion: EMS preparedness for terrorism requires comprehensive planning, specialized training, and integrated command structures. Strengthening interagency coordination, tactical medical capability, and CBRN preparedness is essential to enhance system resilience, protect responders, and optimize patient outcomes in terrorism-related emergencies.

Key words: Terrorism; Emergency Medical Services; Mass casualty incidents; Triage; CBRN preparedness; Tactical medicine.

Introduction

Terrorism remains a persistent threat that affects civilian populations across many regions of the world. Acts of terrorism take multiple forms and vary in scale and method. These acts include individual assaults using knives or firearms, vehicle-ramming incidents, and explosive attacks, as well as coordinated operations that result in large numbers of casualties, such as the attacks on the World Trade Center on September 11, 2001. In addition to conventional forms of violence, preparedness must also extend to chemical, biological, radiological, and nuclear terrorism, commonly referred to as CBRN events. Such incidents pose distinct challenges due to their potential for delayed recognition, widespread exposure, and long-term health consequences. The

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*Corresponding author e-mail: sweeer0016@gmail.com (Hind mohammed Alqahtani).
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evolution of terrorism has been influenced by the interaction between ideological extremism and digital communication platforms. Social networking channels have enabled rapid dissemination of propaganda, recruitment, and operational coordination, contributing to the global spread of terrorist activity. These dynamics have increased both the frequency and geographic reach of attacks. Terrorist actors seek to maximize harm and public impact by targeting civilian populations rather than military objectives. As a result, locations characterized by high population density and routine civilian activity are frequently selected. Urban environments such as public transportation systems, commercial centers, entertainment venues, and dining establishments have become recurrent targets due to accessibility and crowd concentration [1][2][3].

The deliberate targeting of civilian infrastructure places unique pressure on emergency response systems. Emergency Medical Services are often among the first organized responders to arrive at the scene of an attack. They must operate in environments that may be unstable, insecure, and resource constrained. Unlike routine medical emergencies, terrorist incidents often involve multiple casualties, complex injury patterns, and ongoing threats. EMS personnel may be required to function under conditions that include secondary devices, active assailants, hazardous materials, or mass panic. These factors demand a level of preparedness that extends beyond standard prehospital care. Effective EMS response to terrorism requires integrated planning, specialized training, and coordination with law enforcement, fire services, and public health authorities. Familiarity with tactical response principles, triage under threat conditions, and casualty distribution strategies is essential. Terrorist incidents challenge not only clinical capabilities but also command structures, communication systems, and responder safety. As terrorism continues to evolve in form and execution, EMS systems must adapt to meet these demands and ensure a structured, resilient, and coordinated response aimed at reducing mortality and preserving public safety [1][2][3].

Issues of Concern

The safety of Emergency Medical Services responders at the scene of a terrorist incident represents the foremost operational and ethical priority. Terrorist attacks are inherently unstable scenes, often designed to cause harm not only to civilians but also to responders. The risk of secondary explosive devices is a well-documented tactic intended to target rescue personnel after the initial detonation. For this reason, EMS responders must maintain situational awareness and delay entry until law enforcement and bomb disposal specialists have formally declared the area secure. In active shooter scenarios, scene access is contingent on neutralization of the perpetrator or the presence of responders trained in tactical emergency casualty care and equipped with appropriate ballistic protection. Chemical, biological, or radiological incidents introduce additional hazards, requiring responders to utilize specialized personal protective equipment to prevent contamination and secondary exposure. Structural instability following explosions or fires further elevates the risk of building collapse, while smoke and toxic gas inhalation present immediate and delayed respiratory threats [1]. Blast-related injuries constitute a defining clinical challenge in terrorism-related incidents. Explosive devices used by terrorists are frequently constructed with added shrapnel such as nails, bolts, and metal fragments to maximize lethality. These devices are often compact for concealment or body-worn deployment, facilitating detonation in crowded civilian settings. Urban bombings generate four distinct categories of blast injury, each contributing to the high morbidity and mortality observed in these events [2][3][4][5]. Explosions are deliberately placed in enclosed or semi-enclosed environments to amplify pressure effects. Mortality rates are highest in ultra-confined spaces such as buses and trains, where reflected blast waves intensify tissue damage [5]. Victims of terrorist bombings typically present with higher injury severity scores and require more extensive surgical intervention than patients injured by non-terrorism-related trauma.

Primary blast injuries result from the direct effects of the blast wave and rapid pressure changes. Mechanisms such as spalling, acceleration, and implosion cause significant damage to air-containing organs. The tympanic membranes are particularly vulnerable, with perforation occurring in more than half of individuals exposed to blast pressures exceeding 15 to 50 psi. While tympanic membrane rupture may appear clinically minor, it serves as an important indicator of more severe internal injuries, including blast lung, which occurs at higher pressures and may initially present with subtle signs. Pulmonary barotrauma can lead to alveolar rupture, pulmonary hemorrhage, and air embolism, with coronary or pulmonary air emboli representing a primary mechanism of sudden death in blast victims [4][5]. Secondary blast injuries arise from penetrating trauma caused by high-velocity fragments such as metal, glass, and debris. These injuries can be deceptive, as small external wounds may mask deep tissue penetration by nails, bolts, or pellets. EMS and hospital providers must maintain a high index of suspicion, as retained foreign bodies can cause vascular injury, infection, or delayed hemorrhage. In some cases, biological implantation occurs when bone fragments from the bomber or other victims are driven into surrounding individuals, creating unique infectious and immunologic concerns [6][7][8][9].

Pulmonary injury may result from both primary blast effects and secondary penetrating mechanisms. These injuries can present clinically as pneumothorax, which may be bilateral or tension in nature. Hemothorax is less frequently observed in isolated blast injuries but may occur in the presence of associated penetrating trauma [4][5]. Tertiary blast injuries occur when individuals are physically displaced by the force of the explosion. These injuries are more severe in confined environments, where victims are propelled into solid structures, resulting in blunt trauma, traumatic amputations, or fatal injuries. Quaternary blast injuries encompass a broad range of additional harms not classified within the primary blast mechanisms. These include thermal burns from the explosion or ignited flammable materials, chemical burns, contact burns, and inhalational injuries. Asphyxia from oxygen depletion, exposure to radiation, and acute psychological trauma are also included in this category [10]. Many victims sustain a combination of blunt trauma, penetrating injuries, and burns, producing a multidimensional injury pattern that is characteristic of explosive terrorism and complicates triage and treatment [11]. Penetrating trauma from stabbings and shootings presents distinct patterns in terrorist attacks. Terrorism-related stabbings are more likely to involve large knives, target the upper body, and include multiple wounds, increasing the risk of fatal injury [12]. Firearm-related attacks range from handgun assaults to incidents involving semiautomatic rifles. The use of semiautomatic weapons, capable of firing high-velocity rounds from large-capacity magazines, has been associated with significantly higher casualty counts and injury severity compared to other firearms [13]. These injury patterns demand rapid, coordinated EMS response and advanced trauma care to mitigate mortality in terrorism-related incidents.

Targeted Automobile Ramming Mass Casualty (TARMAC) Attacks

Targeted automobile ramming mass casualty attacks have emerged as a prominent tactic in contemporary terrorism due to their simplicity, accessibility, and capacity to inflict large numbers of casualties within a short time frame. These attacks involve the deliberate use of cars or trucks to strike pedestrians or crowds, often in urban settings where physical barriers are limited and population density is high. The lethality of TARMAC attacks is influenced primarily by the mass and speed of the vehicle, as well as the duration of the assault and the density of the targeted crowd. Larger and heavier vehicles, particularly trucks, generate significantly greater kinetic energy, resulting in more severe injury patterns and higher mortality rates. The clinical presentation of victims involved in TARMAC attacks is dominated by blunt force trauma. Injuries commonly affect the head, chest, abdomen, pelvis, and extremities, reflecting the height of vehicle bumpers and the dynamics of pedestrian impact [14]. Victims may sustain traumatic brain injury, thoracic organ contusions, solid organ lacerations, pelvic fractures, and complex extremity injuries, including crush injuries and traumatic amputations. Secondary impacts, such as being thrown onto hard surfaces or colliding with fixed objects, further compound injury severity. These attacks often generate multiple critically injured patients simultaneously, challenging prehospital triage and overwhelming trauma systems. From an emergency response perspective, TARMAC attacks require rapid scene control, immediate hemorrhage management, and efficient distribution of casualties to appropriate trauma centers.

Chemical Terrorism

Chemical terrorism represents a significant threat due to the widespread availability of toxic substances and the relative ease with which they can be weaponized. Terrorists may exploit industrial chemicals, agricultural compounds, or purpose-developed chemical agents to cause mass harm. Commonly cited agents include organophosphates, frequently used as insecticides, as well as industrial irritants such as chlorine and ammonia [15]. These substances can cause respiratory distress, neurological dysfunction, and systemic toxicity, particularly when released in confined or densely populated areas. Chemical terrorism may also involve substances without legitimate industrial applications, including asphyxiants such as carbon monoxide and vesicants such as sulfur mustard. Exposure routes vary and may include inhalation, dermal contact, or ingestion, each producing distinct clinical syndromes. The challenge for healthcare and emergency responders lies in the early recognition of a chemical event, protection against secondary exposure, and initiation of appropriate decontamination and antidotal therapy. Delayed identification can result in significant responder morbidity and expanded casualty counts. Chemical terrorism thus necessitates preparedness that integrates toxicological knowledge, personal protective measures, and coordination with public health and hazardous materials teams.

Biologic Terrorism

Biologic terrorism involves the intentional release or dissemination of pathogenic organisms or biologic toxins to cause disease, fear, and societal disruption. Such attacks may be carried out by individuals infecting others directly or by organized groups seeking large-scale transmission. Methods of dissemination include aerosolization, contamination of food or water supplies, and deliberate person-to-person spread. Airborne release poses the greatest potential impact, as it enables rapid exposure of large populations before detection. The most concerning biologic agents are classified within Tier 1, previously referred to as Group A, due to their high lethality and public health significance. These include anthrax, tularemia, viral hemorrhagic fevers, and botulism [16]. These agents are characterized by high mortality rates, ease of transmission or dissemination, and the potential to overwhelm healthcare systems. Biologic terrorism presents unique challenges because symptoms may be delayed, nonspecific, or initially indistinguishable from naturally occurring illness. Early cases may go unrecognized, allowing widespread transmission before intervention. Effective response depends on surveillance systems, laboratory capacity, rapid reporting, and close coordination between healthcare providers and public health authorities.

Nuclear Terrorism

Nuclear terrorism encompasses a range of scenarios, including the detonation of a nuclear weapon, the explosion of a radiological dispersal device commonly referred to as a dirty bomb, the sabotage or seizure of a nuclear facility, or the deliberate contamination of water supplies with radioactive material. While the public perception of nuclear events often centers on radiation exposure, historical evidence from Hiroshima and Nagasaki demonstrates that the majority of immediate fatalities resulted from blast forces, projectile injuries, and thermal burns rather than radiation itself [17]. The biologic effects of radiation are dose dependent. Exposure between 2 and 10 Gy is associated with clinically significant injury, whereas lower doses may not require medical intervention and higher doses are typically incompatible with survival. Acute radiation syndrome primarily affects rapidly dividing tissues, with bone marrow suppression and gastrointestinal tract damage representing the most immediate life-threatening consequences. Survivors may experience long-term sequelae, including increased risks of thyroid malignancy, solid tumors, and leukemia [17]. Nuclear terrorism poses profound challenges for emergency medical response, public health management, and long-term care planning, underscoring the need for preparedness that integrates medical, radiological, and security expertise.

Clinical Significance

Effective management of mass casualty incidents resulting from terrorist attacks demands robust command, control, and communication systems, with a particular focus on integrating EMS and hospital administrators into the operational framework. Anticipating surge capacity is critical, as even Level 1 trauma centers may quickly become overwhelmed when confronted with multiple severely injured patients [18]. Contingency plans must therefore include all local hospitals to distribute patient load efficiently, ensuring that no single facility bears the entirety of the response burden. This collaborative planning supports timely triage, treatment, and transfer while optimizing resource utilization across the community healthcare system. A comprehensive command structure enhances operational coordination and situational awareness. The inclusion of a Law Enforcement Medical Coordinator (LEMC) is recommended to bridge the operational and medical domains. Acting as a tactical medical officer, the LEMC provides continuous guidance on both EMS and law enforcement considerations, advises on operational limitations of medical plans, and facilitates integration between protection and rescue elements. This role includes monitoring threats to law enforcement personnel in the hot zone and to EMS and fire personnel operating in the warm zone, allowing for real-time adjustments in response strategies. The LEMC serves as a critical liaison among EMS, fire services, and law enforcement, ensuring that clinical interventions align with operational safety and security priorities.

Scene management is essential, particularly in incidents involving chemical, biological, radiological, or nuclear (CBRN) agents. The area around the attack must be systematically cordoned into distinct zones. The hot zone represents a non-permissive area of direct danger, while the warm zone serves as a semi-permissive area where triage and basic life-saving interventions occur. The outer cold zone is considered a permissive environment, typically housing the casualty collection point where advanced care can be delivered safely. Effective zoning ensures that clinical personnel operate within environments appropriate to their level of protective equipment and training, minimizing the risk of secondary injuries to responders. Security in all zones is vital, as secondary attacks, including additional explosive devices, pose a documented threat to EMS personnel. Verification from law enforcement or security teams that a scene is secure is mandatory before initiating resuscitation or triage. Tactical medical officers must also be equipped with personal protective equipment such as Kevlar vests or body armor and prepared to operate in environmental hazards, including wet surfaces and potential electrical risks. Specialized tactical teams are often required for high-risk or multiple-attacker incidents. Hazardous Area Response Teams, frequently composed of SWAT paramedics or similarly trained personnel, operate within the hot zone to perform essential life-saving interventions such as hemorrhage control, airway management, and rapid evacuation. These teams maintain mobility, carrying limited equipment to facilitate rapid extraction rather than prolonged care, reflecting the prioritization of immediate life preservation under hostile conditions [19]. In contrast, the cold zone allows full clinical capabilities, including advanced airway management, rapid sequence induction, and analgesia, while the warm zone functions as a transitional space where care is delivered under controlled exposure to residual threats. In CBRN incidents, appropriate personal protective equipment is required to continue treatment safely, including tourniquet application and needle decompression for tension pneumothorax.

Structured protocols further enhance the efficiency and safety of first responders. The "3 Echo Protocol"—Enter, Evaluate, and Evacuate—focuses on early casualty identification by law enforcement, immediate management of life-threatening hemorrhage, and rapid evacuation to safer zones [21]. Similarly, the THREAT model—Threat suppression, Hemorrhage control, Rapid extrication, Assessment, and Transport—provides a sequential framework for prioritizing interventions and maintaining operational safety [22]. Both approaches emphasize integration of tactical awareness with clinical decision-making, enabling EMS personnel to maximize survivability while minimizing their own risk. In summary, clinical significance in terrorist-related mass casualty events extends beyond the application of medical interventions to include strategic planning, scene management, responder safety, and interagency coordination. Understanding zone-based operations, integrating tactical medical expertise, and adhering to standardized protocols ensures that EMS can deliver effective care under conditions of extreme risk while maintaining the structural integrity of the broader emergency response system.

Triage

Field triage is a critical component of emergency medical response during mass casualty incidents, particularly in the context of terrorism. Several structured triage protocols exist to rapidly assess and prioritize patients based on injury severity and the likelihood of survival. Among the most widely utilized are START (Simple Triage and Rapid Treatment), SALT (Sort, Assess, Life-Saving Interventions, Treatment, and/or Transport), Triage Sieve and Sort, and CareFlight Triage. START evaluates a patient's ability to follow commands, respiratory rate, and either radial pulse or capillary refill to determine priority. SALT incorporates life-saving interventions into the triage process, combining assessment, immediate treatment, and transport decisions. Triage Sieve and Sort relies on respiratory rate and either capillary refill or heart rate to categorize casualties, whereas CareFlight Triage focuses on command-following ability, presence of respiration, and palpable radial pulse. The implementation of a standardized triage protocol ensures consistent decision-making and efficient allocation of limited resources during chaotic mass casualty scenarios [23],[24]. Lessons from operational experience have refined triage strategies in high-risk environments. For example, Magen David Adom (MDA), Israel's national EMS service, implemented the "save and run" approach during suicide bombings between 2002 and 2005. In this method, EMS interventions at the scene are limited to essential life-saving measures, such as hemorrhage control via bandages or tourniquets, airway management including intubation, and needle decompression for tension pneumothorax. Severely injured patients are typically transported directly to the nearest Level One trauma center, while others may initially be stabilized at closer medical facilities and subsequently transferred for definitive care. This approach prioritizes rapid extrication and minimizes the time victims spend in an unsafe environment, optimizing survival for patients with life-threatening injuries [25].

Management of catastrophic hemorrhage is central to triage operations. Direct pressure using bandages is the first-line intervention for life-threatening bleeding. Extremity hemorrhage may necessitate the application of tourniquets, ensuring proper tension of the windlass to achieve effective hemostasis. Hemostatic agents, alone or combined with junctional tourniquets, are employed for bleeding in areas such as the axilla and groin. In addition to controlling hemorrhage, elevation and splinting of injured limbs are critical to limit further trauma. Pelvic fractures, particularly in unstable patients, may require improvised pelvic binders, often using sheets or other available materials, to prevent exsanguination and facilitate safe transport [26]. Chemical terrorism introduces additional complexity to triage and care. EMS responders must don appropriate personal protective equipment (PPE), ranging from Level A protection—which includes chemically resistant suits and full-face self-contained breathing apparatus—to Level D, consisting of basic overalls without respiratory protection. Higher-level PPE reduces operational mobility and complicates patient care, but is necessary to prevent secondary contamination. Some protocols advocate initial decontamination during transport, with EMS personnel assisting victims in removing contaminated clothing within the ambulance, followed by definitive decontamination upon arrival at a hospital. Basic resuscitative measures and administration of antidotes can be performed en route, balancing the need for rapid evacuation with patient stabilization [15].

Biological terrorism further impacts triage operations. The type of pathogen determines the precautions required for both EMS personnel and patients. Measures may include contact, droplet, and airborne precautions, including the use of N95 respirators. Patients may need to be isolated to prevent disease transmission in both prehospital and hospital settings. In certain cases, EMS providers require pre-exposure or post-exposure prophylaxis, such as for smallpox or anthrax, to mitigate occupational risk while providing care. These considerations underscore the importance of integrating infectious disease protocols into triage systems, ensuring safety for responders while optimizing patient outcomes [16]. In sum, triage during terrorism-related mass casualty events involves structured assessment protocols, rapid identification of life-threatening injuries, and situationally appropriate interventions. Effective hemorrhage control, chemical and biological hazard management, and adherence to standardized triage systems are essential to maximize survival, maintain responder safety, and ensure efficient use of available medical resources.

Radiological and Nuclear Terrorism

Management of radiological and nuclear incidents requires a structured and highly protective approach to ensure both responder safety and effective patient care. Personal protective equipment is mandatory and typically includes respiratory protection, eye shields, gowns, gloves, and boots to prevent contamination from radioactive particles. Scene management is organized into clearly defined zones: the hot zone, where direct contamination is present; the warm zone, functioning as a buffer for triage and initial care; and the cold zone, designated as a safe area for definitive treatment and coordination [27]. Victims exposed to radiological materials must be systematically evaluated to determine the level and type of contamination. Geiger counters or similar radiation detection devices are used to quantify exposure, guiding subsequent interventions. Contaminated clothing is removed carefully and double-bagged to prevent further spread of radioactive particles. Patients then undergo thorough decontamination, which includes facial rinsing and comprehensive skin washing using soap and water. Depending on the type of exposure and absorbed dose, internal decontamination measures may also be necessary, potentially involving administration of chelating agents or other medical therapies to mitigate systemic contamination. Efficient decontamination protocols, combined with proper zoning and PPE usage, minimize the risk to both responders and other patients while ensuring the continuity of medical operations.

The psychological impact of terrorist attacks, including radiological or nuclear events, is significant and often comparable to other mass casualty incidents. EMS providers and other frontline responders frequently experience acute stress reactions, with some developing post-traumatic stress disorder (PTSD) or depressive symptoms in the aftermath [28]. Implementing structured support systems is essential to preserve the mental health and operational effectiveness of healthcare personnel. Critical incident stress counseling should be readily available and integrated into disaster response plans, beginning at patient arrival and continuing throughout the duration of care. Preventive measures for responders include comprehensive disaster preparedness training, scheduled critical incident stress debriefing, and regulated shift work during prolonged responses. Such measures not only reduce the risk of acute and long-term psychological distress but also maintain team functionality, situational awareness, and decision-making capacity under extreme conditions. Addressing both the radiological risks and the psychological burden ensures a holistic response strategy, protecting responders while optimizing patient outcomes in the context of nuclear or radiological terrorism.

Conclusion

Ensuring scene safety is the foremost priority before permitting first responders to enter any area affected by a terrorist incident. Verification by law enforcement or security personnel that the environment is secure is essential to prevent secondary injuries from additional attacks, structural collapse, or hazardous materials. Without this precaution, responders themselves may become casualties, which would further strain emergency response capabilities and compromise patient care. Coordination of personnel and medical resources is equally critical. Effective integration of EMS, hospital systems, law enforcement, and other emergency services ensures that patient triage, treatment, and transport are conducted efficiently. Clear delineation of roles, responsibilities, and communication channels enhances operational efficiency and allows for rapid decision-making, particularly when the number of casualties is high and time-sensitive interventions are required. Awareness of the multidimensional nature of blast injuries is essential for accurate assessment and treatment. Patients exposed to explosives may present with complex trauma patterns, including head injuries, burns, blast lung, and intra-abdominal or thoracic injuries. The presence of chemical, biological, or nuclear contamination further complicates clinical management, necessitating both decontamination and specialized medical interventions. Comprehensive preparation, including training, resource planning, and interagency coordination, is therefore imperative to optimize patient survival, protect responders, and maintain the functionality of the broader healthcare and emergency response system in the aftermath of terrorist events.

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