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APPROACHES TO HANDLING MAJOR INCIDENTS INVOLVING CHEMICAL, BIOLOGICAL, RADIOLOGICAL, AND NUCLEAR HAZARDS

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Abstract: *Managing casualties in chemical, biological, radiological, and nuclear (CBRN) incidents poses distinct challenges. These events have a disproportionate impact on both emergency personnel and infrastructure. While encounters with CBRN incidents are rare, it's essential to plan and train comprehensively, employing a universal approach to all potential hazards. Effectively managing CBRN incidents necessitates prompt identification of the agent involved, demanding specialized knowledge among responders. Understanding factors such as toxicity, latency, and persistency is critical in handling chemical incidents for appropriate casualty prioritization and intervention. Distinguishing between live biological agents and toxins is crucial in managing biological threats. The characteristics of live agents, including virulence, pathogenicity, infectivity, transmissibility and lethality, vary and require tailored management. Similarly, radiological and nuclear hazards, which may result in irradiation, contamination, or trauma, demand a structured approach to response efforts during major incidents. All healthcare professionals involved in such incidents must grasp the principles of CBRN incident management to mount a proficient reaction.*

Keywords: CBRN, chemical, biological, radiological, nuclear

1. Introduction

CBRN agents have been used in warfare throughout history, and there have also been numerous accidental releases of hazardous chemicals, biological substances or nuclear materials. In their attacks, both terrorist groups and state-sponsored actors are increasingly employing a range of CBRN agents, from rudimentary to sophisticated. Not only do such actions escalate the potential for casualties, but they also create major hurdles during the cleanup phase, damage infrastructure, and instill fear and panic among populations. Raising awareness of CBRN threats within the medical community is crucial. Enhancing understanding of various CBRN agents and their pathophysiology can lead to improved management strategies, ultimately enhancing patient outcomes.

2. Key Guidelines in CBRN Incident Management

The key guidelines of CBRN incident management, provide a structured framework for effectively managing incidents [1], [4].

These principles are:

- Security
- Barriers
- Leadership
- Connectivity
- Evaluation

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- Sorting
- Therapy
- Conveyance
- Utilization
- Retrieval

3. Recognition of CBRN Incidents

Emergency services may find themselves in an unfamiliar environment when CBRN incidents occur suddenly.

In this scenario, there could be numerous distressed and deceased individuals or animals, as well as people showing inexplicable symptoms like respiratory tract irritation, skin, eye, sweating, vomiting and seizures. Additionally, there might be obvious indications of hazardous materials, like unusual smells, tastes and the presence of unexplained mist clouds, vapors or drops of oil. The deployment of traditional weaponry can function as a diversion, masking the existence of CBRN agents and heightening the risk to emergency responders, thereby delaying treatment for victims. Henceforth, the occurrence of a CBRN event would perhaps not be instantly discernible, with detection possible through identifying toxidromes within or following primary casualty care. The "Table 1: Safety Triggers for Emergency Personnel (STEP) 1-2-3 Plus" is an invaluable resource for emergency responders when faced with incidents of uncertain causation.

Table 1 Safety Triggers for Emergency Personnel (STEP) 1-2-3 Plus[3]

Step	Number of casualty	What to do?
1	One	Utilize the standard operating procedure for this situation. The probability of CBRN contamination is low.
2	Two	Exercise vigilance and explore all avenues. Potential CBRN contamination exists. Notify upon arrival and maintain communication with command. Adhere to Step 3 guidelines if contamination is evident or suspected.
3+	Three or more	Proceed with added caution: Refer to the CBRN initial responder flowchart. Central principles involve eviction, communication, unclothing, and decon.

4. Types of CBRN Hazards

4.1. Chemical Hazard

Chemical dangers are faced every day, both at home and in industrial workplaces.

These dangers cover a wide range of impacts, from fatal outcomes to minor symptoms.

Materials that present these risks include domestic chemicals, harmful industrial substances, and chemical warfare agents.

Although there is some overlap between these categories, the approach for handling any chemical hazard depends on its specific properties. [3]

These include:

- *Toxicity:* Indicates the dose of a chemical, based on the exposure route, that can lead to clinical effects or poisoning.
- *Latency*: Signifies the duration between exposure to a chemical and the onset of symptoms.
- *Persistence*: Relates to the physical characteristics of a chemical that define the possible danger of secondary contamination to emergency personnel. For example, someone who has inhaled carbon monoxide does not endanger emergency room staff, while a person contaminated with asbestos particles or VX agent represents a significant threat.

4.2. Biological Hazard

Biological hazards are categorized into two principal types: live agents (microorganisms) and toxins.

This differentiation is crucial due to the significantly varying risks and medical management strategies for each type. Live biological agents encompass bacteria, viruses, and fungi.

Infections from these agents can lead to diverse outcomes, ranging from incapacitation (like with Salmonella) to death (as seen in viral hemorrhagic).

Additionally, those infected may present a contagious threat.

Materials such as sewage, blood, spores, and feces may be involved in certain instances of biological contamination.

Such situations necessitate a consistent approach encompassing risk assessment, containment, decontamination, and isolation. Several factors are considered when evaluating the characteristics of live agents:

- *Pathogenicity:* Indicates the potential to cause disease, which can differ among various strains of microorganisms;
- *Virulence*: Compares the severity of the disease, with examples such as bird flu compared to H1N1 flu;
- *Lethality*: Reflects the mortality risk, for example, the mortality rate for untreated anthrax inhalation is 100%, whereas for pandemic flu, it is assumed to be 3-5%.
- *Infectivity*: Illustrates the likelihood of infection establishment after exposure, as exemplified by the comparison between hepatitis B and HIV transmission risks subsequent to a needle-stick injury.
- *Transmissibility*: Represents the potential for *person to person* transmission, as measured by the basic reproduction number (R0), indicating the average number of individuals that a contagious person can spread the infection.

Biological toxins are fundamentally chemical substances originating from living organisms, sourced from bacteria, plants, animals, or fungi. These toxins may be used as weapons (e.g., *botulinum or ricin*) or encountered naturally through infections, ingestion of plant toxins, or animal envenomation resulting from bites or stings [4]. Although toxins themselves are not communicable, they present a contamination risk. Assessing toxin risks involves utilizing standards comparable to those employed for chemicals, encompassing factors such as toxicity, latency, and persistence. Wounds have the potential to be exposed to contamination from toxins, or live agents, such as blood-borne pathogens.

4.3. Radiological Hazard

Energy emitted during the decay of radioactive materials and from specific equipment like X-ray machines constitutes ionizing radiation. Distinct effects are produced by various types of radiation due to their differing properties [1]. For example, alpha particles have a limited range and cannot penetrate the skin because they lose momentum quickly upon release. They become dangerous if they are inhaled, injected, ingested or enter through open wounds, though intact skin usually blocks them. Conversely, beta particles can travel further and penetrate deeper into body tissues, posing a serious threat if absorbed, inhaled or ingested. Beta radiation poses a significant threat to the eyes, which are especially susceptible to damage. Some defense against beta particles is provided by protective clothing and equipment. X-rays and Gamma rays can travel greater distances compared to other radiation types. Gamma rays cause more extensive damage than other forms of radiation because, despite interacting less with tissues, they can penetrate deeper into the body.

4.4. Nuclear Hazard

During the initial stage of a nuclear incident, survivors might encounter neutron exposure, a highly damaging form of radiation that penetrates deeply into tissue. While neutrons are short-lived, remaining materials emit alpha, beta, and gamma radiation, presenting ongoing risks. Radiological and nuclear incident management is often combined due to the similar damage caused by ionizing radiation. Exposure can result from accidents or intentional releases. It is essential to distinguish between exposed but non-contaminated individuals and contaminated patients for accurate risk assessment [2]. Understanding CBRN agents aids in early recognition, impacting decontamination and treatment decisions. Key considerations include toxicity, latency, and persistency.

4.5. CBRN Incident Site

Distinct zones with varying risks and intervention requirements make up a CBRN incident site.

Hot zone: The specific type of hazard determines the size of this area, which poses immediate and direct dangers to responders and casualties. Gaseous hazards, for example, can spread downwind from the release source, potentially extending their reach. When stepping into the hot zone, responders must prioritize safety by either wearing suitable protective gear or minimizing their exposure time. Before moving on to evacuation for decontamination and subsequent treatment, the process involves a brief assessment, treating severe bleeding, managing the airway, and potentially administering antidotes (if available), followed by providing respiratory support.

Warm zone: In the warm zone, there's a risk of secondary contamination from casualties, equipment or personnel moving out of the hot zone. The decontamination procedures start here, ideally to be concluded before departure. Before leaving, responders must also decontaminate both themselves and their personal protective equipment (PPE). Furthermore, secondary warm zones might be established for decontaminating contaminated casualties transferred from the scene.

Cold zone: Following the hot zone, initial life-saving interventions and decontamination are conducted before transitioning to the cold zone.

Typically, responders in this zone do not need to wear PPE, though this could vary depending on the type of hazard present.

4.6. Triage

Triage represents the initial clinical assessment and is prioritized alongside decontamination.

The procedure can be carried out during every stage of patient extraction, encompassing both the ingress and egress departing decontamination sites.

Decontamination assumes a pivotal role in reducing additional uptake of specific dangers or enhancing accessibility toward initial examinations and life preserving interventions [1].

Moreover, it allows for the provision of definitive treatment within a sterile setting. Recognition of each triage category is denoted by the letter T. Also, CBRN arrangement mirrors the classifications of traditional triage: acute/ instant (T1), critical / medium (T2), overdue / insignificant (T3), and anticipatory (T4).

Swift and non-invasive, the triage sieve method is reproducible, identifying and prioritizing consequential airway, flow or breathing issues adeptly. In settings with restricted resources, it's advisable to implement a “triage and manage” approach, considering the limited medical assets accessible locally. In addition, CBRN events necessitate further factors for ranking (refer to Table 2), which may be included into an adapted triage sieve (Figure 1). CBRN prioritization follows the same categories as conventional triage: immediate/severe (T1), urgent/moderate (T2), delayed/minor (T3), and expectant (T4). The triage sieve is a non-invasive, reproducible, and rapid method that identifies significant airway, breathing, or circulation issues and prioritizes accordingly. In resource-limited settings, a “triage and treat” approach is recommended due to the limited medical resources available on-site. CBRN incidents also require other considerations for prioritization (Table 2), which can be integrated into a modified triage sieve (Figure 1).

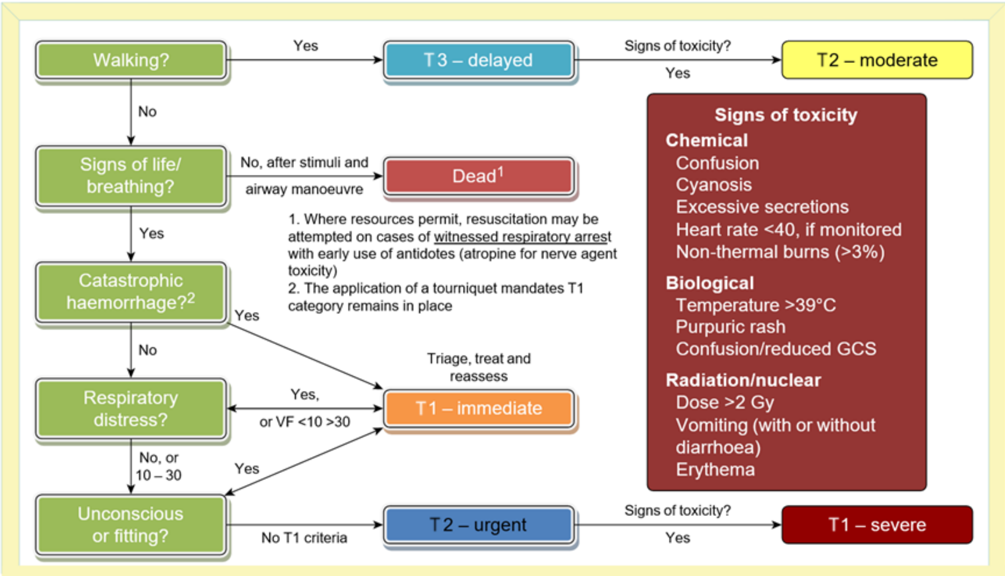

Figure 1: CBRN triage sieve [1]

Table 2 Additional guidelines for triage in CBRN incidents [1]

Chemical	**Biological**	**Radiological/ Nuclear**
Contamination Extreme	Hemorrhagic rash.	For doses exceeding 2 Gy, this can be elevated depending on the number of casualties.
Discharges Insensitive	Sepsis-induced hypotension.	
Burn Non-heating		
Contamination Extreme	Fever (> 38.5˚ C)	
		Diarrhea and/or vomiting history.
		Erythema

5. Handling Contagious Casualties

In certain situations, despite undergoing decontamination, some casualties may continuously pose a hazard. Those who have internal contamination as well as contagious must have to be isolated. It's crucial not to bring such casualties into areas with high patient turnover. Movement within the hospital should be restricted, and patients should be provided with respiratory protection to minimize aerosol spread. Healthcare workers attending to these patients should adhere strictly to infection control protocols to prevent transmission to themselves or other patients. Regular monitoring and testing may also be necessary to assess the extent of contamination and ensure appropriate management.

6. Summary

The complexities of handling CBRN events are examined in the article, highlighting the significance of awareness and comprehension among medical professionals. It outlines key principles for CBRN incident management, including safety, communication, triage, treatment, and recovery. Recognition of CBRN incidents involves identifying various indicators, such as unusual symptoms and hazardous materials, amidst potential distractions. Early recognition is influenced by understanding the characteristics of CBRN agents, shaping decisions on decontamination and treatment. The article also discusses the different types of CBRN hazards, their pathophysiology, and management strategies. Additionally, it highlights the delineation of CBRN incident sites into hot, warm, and cold zones, each requiring specific interventions. Triage plays a crucial role in prioritizing casualties for treatment, considering the severity of their condition and contamination risk. Finally, the article addresses the handling of contagious casualties, emphasizing the importance of isolation and infection control measures to prevent further transmission. Overall, the article underscores the need for preparedness, collaboration, and adherence to protocols in effectively managing CBRN incidents and mitigating their impact on public health and safety.

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