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REVIEW ARTICLE

Prehospital preparedness of health systems against chemical, biological, radiological, and nuclear (CBRN) threats: A review

Kimyasal, biyolojik, radyolojik ve nükleer (KBRN) tehditlerine karşı sağlık sistemlerinin hastane öncesi hazırlığı: Bir derleme

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Abstract

This review aims to highlight the importance of prehospital interventions in response to Chemical, Biological, Radiological, and Nuclear (CBRN) threats, evaluate findings from international literature, and analyze the current situation in Türkiye to present systematic recommendations. The study was conducted by reviewing national and international literature. Data were obtained from PubMed, Google Scholar, the Turkish Ministry of Health, AFAD, and related official documents, and were analyzed accordingly. The review covers the general definition of CBRN threats, challenges in prehospital response, current practices, gaps in training, and examples of good practices. International literature indicates that health systems are inadequately prepared for CBRN incidents, with lack of knowledge and experience among personnel negatively affecting response effectiveness. Key concerns include decontamination, use of personal protective equipment (PPE), and scene safety. In Türkiye, awareness of CBRN threats increased after the 1999 Marmara earthquake, leading to the establishment of CBRN units by the Ministry of Health and AFAD. Despite this, CBRN scenarios are still underrepresented in disaster plans, training efforts are not widespread, and preparedness levels in rural areas remain low. The presence of UMKE teams, decontamination units in city hospitals, and partial drills are seen as positive developments. Strengthening knowledge, equipment, and organizational capacity is essential to enhance prehospital response to CBRN incidents. In Türkiye, raising awareness of CBRN, expanding training for UMKE and 112 teams, increasing field exercises, and updating disaster plans are recommended. A multi-stakeholder, scenario-based preparedness process will contribute to national health security.

Keywords: CBRN, prehospital emergency healthcare, decontamination, emergency response, health training.

Özet

Bu derlemenin amacı, Kimyasal, Biyolojik, Radyolojik ve Nükleer (KBRN) tehditlerin hastane öncesi müdahale süreçlerindeki önemini ortaya koymak, bu alandaki uluslararası literatür bulgularını değerlendirmek ve Türkiye'deki durumu analiz ederek sistematik öneriler sunmaktır. Çalışma, ulusal ve uluslararası literatürün incelenmesi yoluyla hazırlanmıştır. PubMed, Google Scholar, Sağlık Bakanlığı, AFAD ve ilgili kamu kurumlarına ait resmi dokümanlar taranarak elde edilen veriler analiz edilmiştir. Derleme kapsamına KBRN tehditlerinin genel tanımı, hastane öncesi müdahalede karşılaşılan zorluklar, mevcut uygulamalar, eğitim eksiklikleri ve iyi uygulama örnekleri alınmıştır. Uluslararası literatürde, KBRN olaylarına yönelik sağlık sistemlerinin hazırlık düzeyinin yetersiz olduğu, personelin bilgi ve tecrübe eksikliğinin müdahaleyi olumsuz etkilediği belirlenmiştir. Özellikle dekontaminasyon, kişisel koruyucu donanım kullanımı ve olay yeri güvenliği gibi konular öne çıkmaktadır. Türkiye'de ise, 1999 Marmara depreminden sonra KBRN farkındalığı artmış, Sağlık Bakanlığı ve AFAD gibi kurumlar çeşitli eylem planları ve eğitim programları geliştirmiştir. Ancak halen KBRN senaryolarına afet planlarında sınırlı yer verildiği, eğitimlerin yaygınlaştırılamadığı ve kırsal bölgelerde hazırlık düzeyinin düşük olduğu tespit edilmiştir. UMKE ekipleri, şehir hastanelerindeki dekontaminasyon üniteleri ve kısmi tatbikatlar olumlu gelişmeler olarak değerlendirilmiştir. KBRN olaylarına karşı hastane öncesi müdahale süreçlerinin etkinleştirilmesi için bilgi, ekipman ve organizasyonel kapasitenin güçlendirilmesi gerekmektedir. Türkiye özelinde, KBRN ile ilgili farkındalık düzeyinin artırılması, UMKE ve 112 ekiplerine yönelik özel eğitimlerin yaygınlaştırılması, saha tatbikatlarının artırılması ve afet planlarının güncellenmesi önerilmektedir. Çok paydaşlı, senaryoya dayalı bir hazırlık süreci, ulusal sağlık güvenliğini güçlendirecektir.

Anahtar Kelimeler: KBRN, hastane öncesi acil sağlık hizmeti, dekontaminasyon, acil müdahale, sağlık eğitimi.

INTRODUCTION

With the diversification of global security threats in recent times, Chemical, Biological, Radiological, and Nuclear (CBRN) incidents have emerged as serious situations threatening both civilian populations and healthcare systems. Such events may arise naturally, but they can also occur due to accidents or intentional attacks.

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Scenarios such as chemical leaks in industrial zones, the spread of infectious diseases through biological agents, accidents involving radioactive materials, and the threat of nuclear weapons represent complex emergency risks faced by modern societies (1).

Most CBRN incidents are high-risk situations where the first few minutes of intervention are critical. Therefore, prehospital emergency healthcare services play a key role in these situations. It is crucial that the first responders at the scene correctly identify the threat, ensure the protection of themselves and the public, and effectively implement decontamination and triage procedures. The successful execution of these tasks not only increases the survival chances of individuals but also helps prevent the collapse of the healthcare system by reducing the patient load directed to hospitals (2).

Research has shown that the capacity to respond to CBRN incidents depends largely on education and preparedness. For instance, a study conducted in Qatar revealed that healthcare workers had insufficient knowledge about CBRN threats and that educational programs could make a significant difference in this field (3). Similarly, a follow-up study by the same research group emphasized that prehospital healthcare providers need substantial improvements in preparedness both at the individual and institutional levels to effectively respond to CBRN events (4).

Historical data also clearly illustrate the importance of preparedness in this area. The sarin gas attack that took place in the Tokyo subway system in Japan in 1995 revealed significant deficiencies in scene safety and decontamination practices by healthcare professionals, which led to secondary injuries (1). This incident highlighted the need for both institutional and personal preparedness, including proper intervention planning and equipment.

Moreover, CBRN threats disproportionately affect vulnerable groups such as children. Due to anatomical and physiological differences, children are at greater risk in such incidents. This necessitates the development of specialized response protocols by healthcare providers (5).

Following the 1999 Marmara Earthquake, significant structural reforms were implemented in Turkey's disaster management and healthcare services, which also accelerated preparedness efforts against Chemical, Biological, Radiological, and Nuclear (CBRN) threats. In 2014, the Turkish Ministry of Health published the CBRN Directive, which defined the roles and responsibilities in this area and aimed to establish CBRN units and provide specialized training for personnel (6). However, various challenges persist in practice. Field studies have revealed that especially in rural regions, healthcare and emergency response personnel have inadequate knowledge and experience regarding CBRN incident management, and there are serious deficiencies in training and equipment (7). This situation demonstrates that CBRN preparedness in Turkey varies by region and that structural problems such as lack of resources and insufficient personnel continue to hinder effective readiness.Considering the unpredictability and high destructive potential of CBRN incidents, prehospital preparedness against such threats must be systematically addressed and improved. An effective initial response system not only mitigates the immediate impacts of emergencies but also enhances the overall disaster resilience of the community.

Unlike other types of emergencies, CBRN threats pose the risk of large-scale contamination, secondary injuries, and direct hazards to healthcare personnel. These threats may stem from intentional terrorist attacks, industrial accidents, or naturally occurring infectious sources (1). Chemical threats often act rapidly, whereas biological agents may progress insidiously and be detected later. Radiological and nuclear incidents can cause long-term physical and psychological impacts across wide populations (2).

In Türkiye, the proximity of large industrial zones to urban centers (8) increases the risk of chemical accidents. Additionally, regional conflicts in neighboring areas (9) raise the potential for cross-border biological and chemical threats.

TYPES OF CBRN THREATS AND THEIR IMPACT ON HEALTH SYSTEMS

Chemical Threats

Nerve agents (e.g., sarin, tabun, soman, VX), pulmonary irritants (e.g., phosgene, chlorine), and vesicants like

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sulfur mustard are among the most toxic chemical warfare agents, known for causing severe and rapid effects on the human body (9). Because chemical attacks produce immediate consequences, rapid intervention and decontamination are vital.

Biological Threats

Biological threats spread through viruses, bacteria, toxins, or other pathogens. SARS, Ebola, and more recently, the COVID-19 pandemic, have demonstrated the far-reaching global impact of such threats (10). These agents can spread before symptoms appear, so prehospital teams must be trained in early recognition, isolation, and contact precautions.

Radiological and Nuclear Threats

A study comparing the Chernobyl and Fukushima disasters reported that Chernobyl had more severe health and environmental consequences. Both incidents involved widespread radionuclide release, causing long-term health effects due to ionizing radiation (11). In cases of radiation exposure, prehospital personnel must be competent in decontamination and dose estimation.

The Importance of Prehospital Intervention

First responders at the scene of a CBRN event must not only save lives but also prevent the spread of contamination, conduct decontamination, and apply effective triage protocols to preserve the integrity of the healthcare system. Early recognition and appropriate intervention directly influence individual outcomes and societal resilience (3).

Critical tasks during the prehospital phase include: • Ensuring scene safety • Performing decontamination based on the threat type • Using personal protective equipment (PPE) • Conducting effective triage and evacuation • Maintaining communication with receiving hospitals (4)

While Türkiye's 112 emergency health system is widespread (6), specialized training for CBRN-specific interventions is not systematic. PPE usage and access to decontamination equipment are especially limited (12).

Current Preparedness Levels and Training Deficiencies

Studies from Qatar show low knowledge levels among healthcare workers, inadequate training, and significant gaps in practical application (5, 13). In many countries, CBRN preparedness plans exist only on paper, and personnel are often unaware of or untrained in their implementation (13).

Additionally, emergency medical services frequently focus on trauma or cardiac arrest scenarios, while preparedness for rare but high-impact CBRN events remains limited (14).

Although the Turkish Ministry of Health has provided CBRN training in specific centers, it has yet to reach all frontline personnel. Disaster plans often fail to incorporate detailed CBRN scenarios (16).

Children and Other Vulnerable Groups

Children are particularly vulnerable in CBRN events due to their physiological and developmental differences. They are more sensitive to toxic agents, affected more rapidly, and may exhibit different symptoms compared to adults. Thus, response algorithms tailored to children are needed (17).

In Türkiye, pediatric hospitals and emergency units are typically integrated into general disaster plans. However, CBRN-specific awareness and protocols for children remain underdeveloped (6).

Good Practice Examples and System Models

In Qatar, the "RSDAT" protocol (Recognition, Safety, Decontamination, Antidote, Transport) has been used in HazMat-CBRN scenarios to streamline prehospital management (5). Such acronyms improve decision-making speed and reduce errors in high-stress environments.

Although some Turkish city hospitals are equipped with CBRN decontamination units, their availability is limited. Additionally, training levels of special units like UMKE are planned to be enhanced (18).

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Training and Policy Recommendations

Key steps to strengthen CBRN preparedness include:

- Conducting regular, scenario-based drills for healthcare personnel
- Mandating specialized training modules
- Ensuring easy access to PPE and decontamination kits
- Establishing regional collaborations and national action plans (1, 14)

CBRN threats are unpredictable and highly destructive. Therefore, prehospital emergency healthcare systems must be equipped with adequate knowledge, skills, and equipment. Structured training, a strong logistics infrastructure, and efficient emergency protocols will boost societal resilience.

The CBRN units within the National Medical Rescue Team (UMKE) form the backbone of Türkiye's institutional preparedness (12). However, it is essential to update field manuals and increase scenario-based simulations (19).

DISCUSSION

This review highlights the critical role of prehospital intervention in response to CBRN threats and reveals significant deficiencies in current systems. A recurring issue in the literature is the inadequate knowledge and practical preparedness of healthcare professionals, which falls short of addressing the complex nature of CBRN incidents (5, 13). This inadequacy not only poses individual health risks but can also lead to cascading consequences such as outbreaks, radiation dissemination, or the widespread exposure of populations to chemical agents (1, 3).

The rarity of CBRN events often leads to the deprioritization of training in this area. However, given the potentially devastating outcomes of these low-frequency but high-impact events, health systems must develop dedicated preparedness strategies. As demonstrated in the case of Qatar, structured intervention protocols supported by practical training—such as the RSDAT model—can significantly enhance healthcare workers' awareness and intervention competency (14).

Another critical discussion point is the need for special protection measures for children, the elderly, and individuals with chronic illnesses during CBRN incidents. Due to their physiological vulnerabilities and limited defense mechanisms, it is recommended that health systems develop triage and treatment protocols specifically designed for these populations (17).

Even in developed countries, the implementation of CBRN preparedness plans has proven ineffective. A study conducted in public hospitals in Riyadh reported that preparedness plans remained merely as written documents, healthcare personnel were unfamiliar with their contents, and drills were insufficient (14). This suggests that in environments where theoretical plans are not supported by practical training, health systems may fail during a real CBRN event.

In the context of Türkiye, studies have shown that the level of CBRN preparedness is especially lower in rural regions (8), and that coordination problems commonly arise during post-disaster response processes.

CONCLUSION

CBRN threats present a serious test for health systems in terms of both capacity and flexibility. Especially at the prehospital intervention stage, accurate decision-making, rapid decontamination, safe transportation, and effective triage can fundamentally alter the course of an incident. However, existing research points to significant deficiencies in these processes.

In order to strengthen CBRN preparedness in Türkiye, it is essential to improve training, ensure the provision of necessary equipment, update legislation, and enhance inter-institutional coordination. Joint action plans developed by the Ministry of Health and AFAD (8) can play a supportive role in this process.

Recommendations

- Mandatory Training Programs: It is recommended that both theoretical and practical training on CBRN topics be made a mandatory part of in-service education for healthcare personnel (5, 13).
- Drills and Simulations: Organizing periodic drills based on realistic scenarios will enable personnel to gain hands-on experience and applied knowledge (20).

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- Standardized Response Protocols: Algorithms such as RSDAT should be adopted nationally and transformed into practical and applicable field guides (5).
- Guidelines for Vulnerable Groups: Special intervention protocols should be developed for children and other high-risk populations (17).
- Inter-Agency Coordination: Multi-stakeholder response systems should be established, emphasizing collaboration among emergency health services, security forces, and local governments (1, 14).

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